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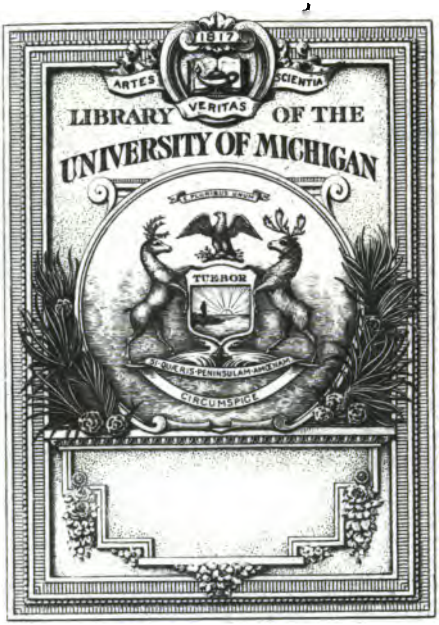

THE GIFT OF

Mrs. John H. Leete

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EVOLUTION, ANTIQUITY OF MAN,

ETC.

SCIENCE IN PLAIN LANGUAGE.

EVOLUTION,
ANTIQUITY OF MAN, BACTERIA,
ETC.

BY

WILLIAM DURHAM, F.R.S.E.

EDINBURGH:
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PREFACE.

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THERE are many intelligent and thoughtful people who have not the time nor, perhaps, the inclination to read regular scientific works, but who would be glad to know the general results of scientific investigation if that knowledge could be imparted to them in plain every-day language without too much detail. For such this book is intended. Each article it contains is short and complete in itself so far as it goes, and may be read without reference to the others. There is nevertheless a connection between the whole of them illustrating the great principle of evolution.

It may be mentioned that these articles have already appeared in the columns of *The Scotsman* newspaper, but I trust they are of sufficient interest to justify me in putting them into the more permanent form of a book.

WILLIAM DURHAM.

January, 1890.

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SCIENCE IN PLAIN LANGUAGE.

I.

NATURAL SELECTION.

THERE is no scientific theory of modern times which has influenced thought in all departments of human inquiry in a greater degree than that of evolution, based on Darwin's great work on the origin of species by natural selection, and no theory has met with greater opposition, as it seems to upset some of our most cherished conceptions and beliefs. Notwithstanding this opposition, however, it has maintained its position as undoubtedly in the main a great truth, however it may have to be modified or added to in details. Owing to the amount of controversy which has taken place, the subject has got somewhat obscured in the popular mind, and it may not be without interest to explain in a general way some of the facts on which it is based. At the root of the whole subject is the fact of natural selection, and we must first understand what this means before we are in a position to judge how far it is able to bring about the changes observed. In the first place, it scarcely needs proof that all living beings, whether animals or plants, produce during their life-time far more of their kind than can possibly survive to maturity, and in their turn give rise to a new generation. Every seed sown produces more than one of its kind; every pair of birds or animals produces more than two; in fact, they all increase in a geometrical ratio, and would soon cover the earth so as to leave no standing room if there was no check. Thus, for instance, a single flesh fly produces twenty thousand larvæ, and these grow so quickly that they reach their full size in five days; so that Linnæus asserts that a dead horse would be devoured by three of these flies as rapidly as would be done by a lion; and it has been calculated that if the progeny of one of these flies went on increasing during three months without check it would have descendants to the number of one hundred millions of billions. Again, if a pair of sparrows were allowed to go on increasing at the usual rate unmolested for ten years, their descendants would number twenty millions or so. Instances of the rapid increase of even the larger animals which produce only one at a time are not wanting. Thus Columbus in his second voyage left a few black cattle at St. Domingo; and these ran wild, and, not being checked, increased so rapidly that twenty-seven years afterwards herds of 4000 to 6000 were not uncommonly met with. Some of these were taken to Mexico, and sixty-five years later as many as 64,000 hides were exported in one year; and these could only represent a small proportion of the cattle which really existed at the time in the wild prairies of that country. It can be shown that plants also exhibit analogous phenomena, so that everywhere throughout the whole realm of animated being this wonderfully lavish reproductive power is present, and yet a sort of general balance is maintained, so that no one species increases beyond certain limits.

It is evident, therefore, that myriads of creatures must be destroyed at all stages of their existence before they reach maturity. The question, then, arises, How is this wholesale destruction of life brought about? And the answer undoubtedly is, by the struggle for existence. Suppose there was one kind of animal or plant inhabiting a certain limited space on the earth's surface, say an island, from which it could derive its food, then it is plain, from the rapidity of increase, that it would speedily fill the whole space with as many of its progeny as could obtain sufficient food. But as the increase in numbers went on the amount of food would be insufficient for all, and a struggle would commence as to which should have the food, and those that were unsuccessful would certainly perish of hunger. Again, suppose that there were two kinds of animals or plants within the same limited area, then, on the same principle, there is sure to be a struggle in the long-run for supremacy, and either the one will destroy the other, or both will be restricted within certain limits; there is no help for it; a number of individuals must be slaughtered to leave room for the others. We know, also, that some animals live by devouring others, and in this case, also, there will be a struggle if the two races meet, the one endeavouring to capture and the other to escape, and a sort of balance is attained, as the one cannot exist without a certain number of the other on which to feed, and the other cannot increase beyond a certain point because it is destroyed by increase of the first. Another form of this perpetual struggle is found in changed conditions of climate, and in rain, wind, snow, and storms of various kinds which destroy numbers of young plants, animals, &c. Nothing can escape the ordeal; it is universal, and every plant, animal, and creeping thing is subject to this great struggle for existence, by means of which the balance of nature is maintained.

Now, since it is quite evident that myriads, we may say the majority, of living things are regularly destroyed in this struggle, we may ask how those that remain have survived. On what principle have they been preserved when so many of their fellows have perished? In the struggle for food between members of the same species, why do certain individuals succeed in getting enough while others perish of starvation? In the fight between rival species, what gives the victory to one rather than to the other? And among those that are preyed upon, why do some escape, while others are caught and destroyed? Is it mere chance; a capriciousness of nature electing some, for no apparent reason, to destruction and others to life? or is there some law guiding and controlling the whole agencies at work, so as to bring about a certain desired end? In some few cases possibly what we usually call chance may have brought about the results, but we may be sure that in the great majority some cause is operating, as nature rarely, we may almost say never, does anything by chance; all is orderly and under the domain of law. To this cause we give the name of "natural selection;" that is to say, nature selects out of the majority of individuals those which are most fitted for her purpose, and preserves them, while the remainder perish. Thus we have what is called the "survival of the fittest," or those which naturally are best able to cope with the conditions under which they live. If, however, a certain number of individuals are thus selected, it must be because they possess some superiority over their fellows; in fact, it shows that even in the same species all the individuals cannot be exactly alike; there must be variation of some kind, however much they may resemble one another generally; some will be strong, others weak; some swift, and others slow, and so on. It is easy to understand, if this be so, how the selection is made. When a number of individual animals are struggling together for food, it is evident that those are most likely to succeed that possess some advantage over their opponents in the way of strength, swiftness, intelligence, &c. Those birds of prey, for instance, which are strongest and swiftest will capture food when their weaker and slower comrades may get none, and among the animals preyed upon, those which are wary and fleet stand a better chance of escaping than those which are stupid and slow. In this way those individuals which are most suited to the circumstances with which they are surrounded, and which are best provided with the means of escaping danger, will be, as it were, picked out or selected to grow to maturity and produce young, and the young will, on the whole, inherit the qualities which were of such use to their parents, although, of course, among them variations will also arise, some being more and some less suited to their surroundings. The same principles can be applied to all plants and animals of every kind, and lead to the same result of preserving those varieties which, on the whole, are best suited to their surroundings.

In order that this natural selection may work at all, it is necessary, as we have already noticed, that there should be variations among individuals, even of the same species, and that among these variations there should be some which are useful in the struggle for existence; for if there were no variations, or if such as there were had no use, then natural selection could do nothing; there would be no material for it to work upon. It becomes, therefore, of great importance to inquire if such variations really do exist. On this point evidence is rapidly accumulating year by year. Before Darwin had shown the importance of this subject, variations from the typical form did not attract much attention; but since then, investigation has shown that these do exist to an extent that was never imagined, even by Darwin himself. Among the lower orders of life these variations are most extensive; thus in the foraminifera, which are little drops of protoplasm secreting variously formed shells, the range is so great that the differences amount to what might be called specific, generic, or even those of orders. Of the common garden snail ninety varieties have been observed, and of the wood snail one hundred and ninety-eight. Among insects, also, there are many variations, and some have been taken for distinct species, although reared from the same batch of caterpillars, and fed together on the same plant. Among the higher orders, such as reptiles, birds, and mammalia generally, the same phenomena obtain, and we find endless variations in every organ of the body, whether external or internal. In individuals of the same species are found great differences in the size of the body, neck, legs, feet, wings, &c., and these differences are not generally proportional; that is to say, we do not find increase of size of body always associated with increased size of the legs or other members, but a larger body may be found associated with smaller limbs, and so on. In fact, each organ varies independently, sometimes in one direction, and sometimes in another, and these variations are not infinitesimal, or even very small. Thus one authority says:—"The facts of the case show that a variation of from 15 to 20 per cent. in general size, and an equal degree of variation in the relative size of different parts, may be ordinarily expected among specimens of the same species and sex taken at the same locality, while in some cases the variation is even greater than this." Further, if we consider any one particular organ, and take the average size of that organ, we shall find that in many individuals that size is exceeded in some instances to a considerable degree, while in others it is not reached, so that the size varies on each side of the mean to very much the same extent.

From these facts, and many others that might be mentioned, there is not the smallest doubt that natural selection has plenty of material to work upon, and almost any possible combination may be obtained. Thus, if rapid flight in birds is useful under certain conditions, then those individuals with long wings and comparatively small and light bodies are selected and preserved. If, on the other hand, fighting powers are advantageous, then those with powerful beaks and claws, strong bodies, and short, firm legs are picked out; and so on through the various circumstances and conditions of life. Whatever is useful in promoting the welfare of any living thing, from the lowest to the highest, is thus naturally selected. The essential qualification is, that the variation, whatever it be, shall be useful in some way in the great struggle for existence. How far this selective process may go on, and to what changes in structure and function it may lead, is a subject for further consideration; but we may accept it as an undoubted fact that natural selection plays an important part in the economy of nature.

ORIGIN OF SPECIES.

HAVING pointed out in the foregoing chapter that in all animated nature there is perpetually going on a great struggle for existence, during which the greater number of the individual forms which arise are destroyed, and that those which remain are naturally selected owing to some variations either in their structure or habits which are useful to them in struggling with their surrounding circumstances, we are now in a position to consider what may be the full effects of this selection carried on through long periods of time, and whether it is competent to give rise to new species, and form a basis for the theory of general evolution. In estimating the effects of natural selection we must take into consideration the facts of heredity. It is generally true that offspring will, on the whole, partake of the nature of their parents, subject, of course, to those variations to which we formerly referred. If the parents be strong, swift, or cunning, so will the offspring be; if the parents have any natural peculiarity of habit or of structure, they will transmit this to their progeny. This is a well-known truth, and could be illustrated by many examples. Therefore, by picking out those varieties in each generation which have this peculiarity in its greatest development, we may gradually increase it, until at length, instead of being only a slight variation, it may become a well-marked character. On this principle all artificial selection made by man proceeds; the gardener and the breeder of cattle carefully select those varieties of flowers or animals which possess the quality they wish to cultivate; and we see the results in our gardens and in our flocks and herds. The greatest variations produced in this way will be found in those animals where fancy or divers uses come into play; and Darwin mentions the domestic pigeon as a remarkable illustration. All the varieties of this bird he traces by many experiments and observations to the wild rock pigeon, which is of a slaty-blue colour, the tail having a dark band across the end, the wings two black bands, and the outer tail-feathers edged with white. In all the domestic breeds he finds these characteristics reproduced under certain conditions; and yet the contrasts between the different kinds are so great that it is difficult to believe that they are all derived from one common ancestor by a process of selection. What could be more different than a pouter and a fantail, a carrier and a tumbler? and yet all these have been developed by taking advantage of slight variations on the original species. Then, again, our domestic dogs are no doubt derived from certain wolf-like species by the same process; and what could be more contrasted than a greyhound and a bull-dog, or a mastiff and a pug? Among vegetables, also, we have such entirely different forms as the cabbage, the cauliflower, and the Brussels sprout, arising from the same original species of plant. In fact, in every department we find this artificial selection producing the most remarkable results by simply picking out and cultivating those varieties in each generation which exhibit the desired quality in the greatest degree. Seeing this is so, it seems reasonable to imagine that natural selection may produce similar or analogous results, and there is no doubt that it does.

Many of the changes of structure brought about are so suited to the surrounding conditions that we can hardly resist the conclusion that they have been cultivated by selection. Thus, for instance, in the island of Madeira many of the insects have either lost their wings altogether or have them so small as to be useless for flight, when in Europe the same species have fully developed wings. Now, why is this? It appears that Madeira is much exposed to sudden gales of wind, and the insects live generally on the coast, where the most fertile land and the greatest vegetation are found. Consequently if these insects possessed wings they would be very liable to be blown out to sea and destroyed. Even a better instance is found in Kerguelen Island, where all the insects are incapable of flight; and these include such well-known forms as the moth and fly. Now, these could not have got to the island without wings even if they had existed in that state elsewhere, which they do not. It is therefore evident they have been reduced to that state by a series of modifications; gradually losing their powers of flight by natural selection, because the stormy and unsheltered nature of their surroundings rendered these powers hurtful to them. Illustrations of this kind might be multiplied almost to any extent. It is evident, therefore, that natural selection is capable of producing results quite as great as any due to artificial selection. If this is so, may it not during long ages have given rise to even greater variations, and brought about the existence of species, the divergence becoming so great by continued selection ?

In the first instance, it is very difficult to define what a species really is. Of course, it is easy to notice the difference between an ass and a horse, for these belong to forms which have greatly diverged. But in the more lowly forms of life the dividing line is extremely obscure, and mere varieties seem to glide insensibly almost into species, so that naturalists have the greatest difficulty in knowing which is a distinct species and which a mere variety of a species already known. In the Sandwich Islands there are a great number of species and varieties of land shells, and a full set of the varieties of each species presents a minute gradation of forms between the most divergent types found in the more widely separated localities. Species, therefore, cannot, in the more lowly forms of life at any rate, be sharply defined, and if natural selection can bring about such varieties as we recognise, it is highly probable that it has also brought about specific changes. For instance, the rook and the crow are quite distinct species, always producing their own kind and never intercrossing, and yet there are about thirty different kinds of birds so like that they are called crows, and some of them differ much less among themselves than does the crow from the rook; and it seems unreasonable to suppose that each kind has descended from one ancestor having all its peculiarities developed from the first. Is it not much more likely that they have all been derived from some common form, and been modified in time by the action of natural selection under varied conditions, much as the rock pigeon has been modified into the various forms of the domestic bird by the intervention of man?

When we consider, further, the great changes of climate, the alterations between the relative positions of land and water, and the numerous elevations and subsidences that have taken place during the long geological ages of the earth's history, we see what powerful agencies have been at work in bringing about alterations of structure and habits of living things, and need not be surprised that these alterations have passed beyond the stage of mere varieties and have reached that of species; have passed, in fact, the very shadowy line which separates these. Consider, for instance, the effects of a gradual increase of cold in any one district of the earth. Natural selection would as gradually pick out those forms of life inhabiting the district which were most suited to stand the lower temperature, and generation after generation of these forms would more and more conform to the structure required by the new conditions; and by the time an Arctic climate had set in they would be so changed as scarcely to resemble in the least their original progenitors. On the other hand, those which could not stand the increasing cold would either perish altogether or migrate to warmer regions, and begin to change in the opposite direction—that is, to adapt themselves by natural selection to a great amount of heat. There would thus, from the same ancestors, diverge two lines of change, ever receding farther and farther apart, and the extreme forms of each line would be perfectly distinct, and have scarcely anything in common, so that they might quite readily take rank as perfectly distinct species or even families. Much the same result would be brought about by the elevation of the land into mountains; for the higher lands would correspond to a colder and the lower to a warmer climate. Again, in a forest-covered district, natural selection would either destroy altogether or drive out into the plain those forms least suited to a sylvan life, and there they would acquire new characters, and thus another line of divergent types be set up. Further, suppose the land so stocked with life that some of the weaker varieties could scarcely live, then it is quite likely that these would attempt to nourish themselves by feeding on water insects such as they could easily catch by wading a little. Natural selection would in this case pick out those forms which could go farthest into the water, and this power would go on developing. The water-ouzels are thought to have acquired their peculiar habits in this way. They feed entirely from the water, under which they can, in a manner, fly, although they are something like thrushes or wrens, but with short wings and tails, and having very dense plumage. This plumage retains so much air that the water cannot reach their bodies, or even wet their feathers to any great extent. In addition to this adaptation, they have strong feet, armed with long and powerful claws, which enable them to hold on to the stones at the bottom of the water while they pick up insects, shells, &c. In all other ways this bird has a close affinity with small perching birds; but we may suppose it has developed by natural selection those peculiarities which enable it to find a living during even the severest winter in an element where it meets with few rivals or competitors. That this sort of development is probable is evident from the habits of some water-thrushes. These birds wade in water, and often plunge head and neck beneath the surface, and their plumage not being impervious, they get wet, but they can give themselves such a good shake that they are dry almost at once so as to be ready to fly. We see here the aquatic habits, as it were, in the process of growth.

Many other instances might be given of similar adaptations. It is quite evident, then, that this theory of the origin of species offers a solution of many difficulties, and gives a rational account of how the endless forms of life in all departments came into being. It is hardly credible that all the varieties of life were originally created as such, and were always distinct as they are now; and if varieties were not separately created, why should species be so, since there is no sharp line dividing them? Is the origin of species by natural selection not a more rational and satisfactory account of the matter? No doubt there are some weak points about the theory which have not yet been cleared; but this is to be expected, as man does not always arrive at the full truth all at once. Even the theory of gravitation has its difficulties, and yet it is undoubtedly true. There may be other agencies besides natural selection helping to originate species, but it is evidently the chief one. Every year proofs of its truth are accumulating from many different quarters, and there is little doubt that before long it will be established as a great law of the universe.

EVOLUTION.

THAT evolution in a certain sense occurs in nature no one who observes at all will deny. We know that living things do not spring into existence at once completely formed, with all their powers fully developed, but are gradually evolved, rising from lower to higher stages, till their structures are complete. The commencement of every living organism is found in a little particle of protoplasm, which, in due course, is developed gradually into the flower, the tree, the insect, the bird, or higher animal, including even man himself. This is a fact which cannot possibly be called in question. Indeed it is so common and evident that we are apt to overlook its significance and take it as a thing of course, just as we do the rising of the sun, without considering the wonderful mechanism by which it is brought about. We have very strong evidence also that a somewhat analogous process of evolution goes on in the formation of the physical universe. Stars and worlds do not start at once from the depths of space into full-orbed glory, but are gradually formed by the slow condensation of cosmic vapour or meteorites, passing through many stages until they reach their full age and splendour. Now, considering what we have noticed in the last chapter on the origin of species, may we not ask if a process of evolution acting through long ages has not brought about the development of all forms of life from the lowest to the highest? It is evident that if the principles that have been noticed explain the origin of species, they are capable also of accounting for the origin of genera, families, &c.; for if varieties shade into species, so do the latter into genera, and so on, ever back and back, towards the original protoplasm, which is the basis of all. As we trace the individual man, with his highly developed and specialised structure and functions, back through various intermediate forms to the original protoplasmic cells, may we not trace also the infinite variety of life-forms which now exist on the earth through intermediate forms, until we reach at length the same simple basis as starting-point for all the complexity? To put it in another way. Was not all life when first created on the earth comparatively simple and structureless, and gradually developed from generation to generation into more and more complex forms, each generation being in the main an advance on the one going before it, until the present state of complexity has been reached, when the forms are so different that nearly all trace of their original relationship has been lost? Just as a tree, for instance, starts from its simple germ, and puts forth first its shoot, then its stem, which divides into branches, and these in turn give rise to leaves, flowers, fruit, &c.

If we had a complete set of specimens of all the forms of life that have ever existed on the earth, we should be able to say certainly whether this is true or not, as we could trace the descent with modifications all through the ages. This, of course, we can never obtain, but we have in the fossils preserved in the rocky crust of the earth fragments of such a set of specimens, not indeed reaching so far back as the beginning of life, but still carrying us to very remote ages, when life-forms were much less developed than now. We may examine, therefore, these fossils, and see whether they support the idea of evolution or not. It is necessary, however, that we should have some idea of what we may expect to find. We must not expect, for instance, all the forms directly between a horse and an ass, for the very good reason that none such ever existed, but we should expect traces, at all events, of forms connecting these to a common ancestor, differing entirely from both; for development takes place like the branching of a tree, and if we suspected two branches to belong to the same trunk we should never look for the connection at the free ends, but should trace them backwards till they approached closer and closer, and were finally merged in the same parent stem. We should expect, also, that as we go back farther and farther in time the forms of life would become simpler, although the changes would be very gradual, and each generation would have a general resemblance to that going before. We might, in a few cases, even find a somewhat unbroken series distinctly connecting one form with another, and be able to trace the various modifications which occurred in the course of time; but, from the very fragmentary nature of the geological remains, this will be rare. Now, in the geological records these expectations are realised, and the evidence all points one way, and that is in the direction of evolution. It is true there are many gaps and abrupt changes which cannot be quite satisfactorily accounted for; although indications of their cause may be given; but every year, as investigations proceed and discoveries increase, these difficulties become less, and many gaps are filled up.

If we examine any department of life, such as plants, for instance, we shall find as a general rule that those of a more simple type occur earliest. Thus the cellular cryptogams, such as algæ, appear in the oldest formations; then somewhat later we find the vascular cryptogams, ferns and their allies, which reach their fullest development in the coal ages; then follow cycads and conifers; and last of all the monocotyledonous and dicotyledonous flowering plants. These different orders make their appearance somewhat suddenly, and cannot be traced backwards towards their common origin; but their whole arrangement is quite consistent with the idea of evolution, and their evidence is only defective, not contradictory. The same story, more or less complete, is told by the remains of other forms of life; the more highly specialised are the more recent, and the simpler the more ancient. Somewhat more definite, although more circumscribed, evidence has also been obtained. In Hungary a great deposit of lake shells was discovered and studied. The beds in which it was found were about 2000 feet thick, and evidently represented the lapse of a great length of time from the first laid down to the last. Now, the shells found in these beds were not of one kind, but presented a regular gradation of form, and could be divided into eight well-marked divisions, and showed that they were all derived one from the other, in regular succession, with connecting-links; and yet some of the later shells differed so much from their original progenitor as to be classed into quite distinct families. Here is an undoubted case of evolution and variation to a large extent in a deposit which had not been disturbed for a very long time, so that none of the variations had been lost, and we find a regular succession of forms differing more and more from each other and from the common parent. Then, again, the difference between crocodiles and lizards is very great, and yet, according to the researches of Professor Huxley, intermediate forms connecting these two are found as we go backwards in the geological record. These have anatomical characteristics intermediate between those of the crocodile and the lizard, and by going back even farther still he finds forms which in some respects approach birds. We have thus a sort of broken line, interrupted in many parts, but still pointing in the direction of evolution of one form from another.

Perhaps, however, the most remarkable and convincing illustration of evolution is to be found in the pedigree of the horse tribe. This family—including the horse, ass, and zebra—has some remarkable characteristics which cannot be mistaken, and is therefore particularly well adapted to show evolution. It is peculiar in the construction of its legs, feet, hoof, and teeth. In most quadrupeds the fore arm contains two bones, while in the horse there is apparently only one; but there are traces of the second bone, which can be observed when carefully looked for. Then the foot of the horse commences at the knee, and is represented by only one greatly enlarged finger or toe, on the end of which the nail expands into what we call the hoof; the other fingers or toes are partly represented in a very rudimentary or aborted form, being of no obvious use to the animal. Analogous modifications are found in the hind legs. The formation of this tribe of animals is therefore very special in these respects. In addition to this, the teeth are also very distinctive, being formed of hard and soft material, specially adapted for grinding vegetable substances. There is, therefore, no danger of confusing this tribe of animals with any others, and it offers peculiar facilities for tracing its ancestry, if such can be found. Now, although the horse did not inhabit America when it was discovered by Europeans, yet its remains are found in profusion in that continent; and not only so, but a series of modified forms are found in the formations as we go backwards in time, until we reach a form which is so distinct from the modern horse that the connection would never have been suspected had not the intervening links been also discovered. Far back in the Eocene formations, several species of an animal about the size of a fox have been found. In these animals the bones of the leg are complete, and they have four well-developed toes, and another rudimentary one on the fore feet, and three toes on the back feet. The structure of the feet and teeth indicate their relation to the horse. A little later this animal disappears, and its place is taken by another very similar in general appearance, but the rudimentary toe in the fore foot has disappeared, and in some other respects it approaches more nearly to a horse. This in its turn disappears, and gives place to one nearly as large as a sheep. It has only three toes on the fore foot, and there are further changes in the teeth and in the bones of the legs, in the direction of assimilation to the horse. A fourth form next appears, still larger than the last, having three toes on each foot, but in other respects advancing in development. Then a fifth appears, much nearer the fully developed horse, being about the size of an ass. This form has still the three toes on each foot, but only the middle one, provided with an incipient hoof, reaches the ground, the other two being apparently of no use. Its teeth, also, are unmistakably more like those of a horse. Last of all comes a form only very little different from the modern animal. It has lost almost entirely the two side toes, and has the central one fully developed; the bones of its legs correspond almost exactly to those of the horse tribe, and its teeth are but little different. After all these five forms have been passed in succession, we come to the remains of the true horse, which had died out, for some reason or other, before the modern discovery of America.

This tracing back of the pedigree of the horse is as near a demonstration of the truth of evolution as could possibly be imagined. There cannot be the least reasonable doubt that the various forms have been evolved the one from the other in regular succession, each advancing somewhat beyond its progenitor in special adaptations; for it is impossible to imagine each as a new creation, varying in such a slight manner from the other. Other analogous cases might be mentioned, but none so complete and striking as this. On the whole, then, evolution, although not actually demonstrated beyond a doubt, has yet so much evidence in its favour that we may fairly accept it as true. Although it may have to be modified in certain directions, and much connected with it is still obscure, yet it hardly admits of a doubt that evolution by descent, with modifications in some form or other, is the key to the creation of all living forms which exist on the earth.

EVOLUTION OF MAN.

The consideration of the evolution of living forms in general as due to natural selection, acting through descent with modifications one from another, is naturally followed by the inquiry whether man himself is included in this arrangement, or whether he has an entirely different origin and history. Man occupies such a unique position, and his moral and intellectual nature separates him by such a wide gulf from the highest of the lower animals, that we may well hesitate before classing him among them.

In discussing the question, however, we may for the present put aside his higher attributes, as these have been considered by at least one naturalist of great eminence to owe their origin to some other agent than natural selection. We may look upon man only as an animal, and inquire if there is anything in his life-history or in his structure which indicates the same or a different origin from that of other animals. In the first place, it may be stated that we have no direct positive evidence whatever that man as an animal has ever been anything different from what he is now; there is no trace of that gradual modification from one form to another, such as has been found so conspicuously in the case of the horse. The oldest human remains which have been preserved for ages in the crust of the earth indicate no essential change in structure; they are not different from the remains of modern men; so that, as Professor Huxley says, "the fossil remains of man hitherto discovered do not seem to take us appreciably nearer to that lower pithecoid form by the modification of which he has probably become what he is." Of course, there is abundant evidence of mental development from the savage, making his stone implement, up to the modern civilised man, but none of change of bodily structure. It may be that as the various regions of the earth are more thoroughly explored his ancestry may be discovered, but at present geology is silent on the subject. Any conclusion, therefore, which may be come to as to his origin and position in the scale of life is based upon the analogy of his bodily form and functions to those of other animals. It is evident, even to the most superficial observer, that man is an animal differing considerably in outward appearance, but in the main the same as others, and on more careful study this becomes more and more evident. His form is constructed, as it were, on the same plan as other vertebrate animals. His backbone consists of a number of jointed vertebræ or small bones, and supports the head; he has a certain number of ribs enclosing and protecting his vital organs. He has four limbs, terminating in fingers and toes. His blood, muscles, nerves, heart with its veins and arteries, his lungs and breathing apparatus, generally correspond to those of other mammalia. In fact, every detail in structure is the same, differing somewhat, no doubt, but only in the same manner as one species differs from another. If we had no *a priori* ideas to get over, we should undoubtedly class him as one with them, although more highly organised, as there appears no essential difference marking him out as something quite different. Further, many animals have rudiments of organs which are useless to them, while these same organs are fully developed in some allied form, and are, therefore, supposed to indicate a common origin for both forms. Thus, for instance, many birds have only rudimentary wings, and the horse, as we have noticed, has the rudiments of two of its lost toes. In man the same phenomenon occurs; thus, he has the rudimentary bones of a tail beneath the skin, and there have been cases where a real external tail has appeared. The different parts of man's structure also vary, and often tend to approximate to those of the lower animals. Thus, one authority states that in a single male subject there were no fewer than seven muscular variations, all of which plainly represented muscles proper to various kinds of apes. Of all the bodily organs, however, the brain has been considered the one by which man is most distinguished from the lower animals, and yet even in it the relationship is clearly traced. We see a regular gradation in this organ from the fish upwards, and there is no sudden break anywhere; it gradually increases in size and complexity through the various classes of animals until it culminates in man. The nearest approach to man's brain is found in those of the apes, which are also most nearly related to him in bodily structure. Every stage of the convolutions in the brain is found among the ape tribe, from the almost smooth brain of the marmoset up to that of the chimpanzee, which differs but little from that of man. As Mr. Huxley says:—"The surface of the brain of a monkey exhibits a sort of skeleton map of man's, and in the man-like apes the details become more and more filled in, until it is only in minor characters that the chimpanzee's or the orang's brain can be structurally distinguished from man's." Even as to size, although man's brain exceeds very largely that of any of the lower animals, yet we find there is a greater difference in weight between the largest and the smallest human brain than there is between the smallest human brain and the largest ape brain. If, therefore, we were to judge by size and weight of brain, we should consider there was a greater difference between the highest and the lowest man than there is between the lowest man and the highest ape. Again, if we compare the skeletons of some of the higher apes, we find they resemble in a most remarkable degree the skeleton of man, every bone corresponding, although differing somewhat in size, proportions, or position. In fact, like the general appearance of the animal, it is a sort of distorted copy of man. Professor Owen says in regard to this subject:—"I cannot shut my eyes to the significance of that all-pervading similitude of structure—every tooth, every bone, strictly homologous—which makes the determination of the difference between Homo and Pithecus the anatomist's difficulty." In the actual differences which are found, man sometimes agrees with one species, although he differs from another; so that it has been said that the structural differences which separate man from the gorilla are not so great as those which separate the gorilla from the lower apes. It must not be supposed, however, that these analogies point to the ape as man's ancestor. This is a common mistake. They only indicate that if evolution be true, the apes and man had a common origin; and if we could trace their forms back through the ages, they would become more and more alike, until they merged into one form in their common ancestor, which would in all probability be greatly different from either. Perhaps, however, the remarkable analogy between man and the lower animals is to be found in the development of the individual. Every animal takes its rise in a little germ of protoplasm, which gradually increases in size and develops in form. Now, up to a certain stage of this development all animals, whether fish, bird, or mammal, are alike: their embryos cannot be readily distinguished one from another. As they grow differences begin to appear, but the more the fully developed animals resemble one another, the greater is the resemblance of their embryos. At a certain stage, for instance, a human being cannot be distinguished from a puppy-dog. A little later the former begins to differ from the latter, but in doing so it becomes like a young ape, and it is only in the later stages that it begins to differ from the ape. Some curious resemblances to animals may be mentioned. At one stage the embryo man has a tail, which is longer than his rudimentary legs. At another stage the convolutions of his brain resemble those of a grown-up baboon. Then the great-toe, which is so distinctive of man in his adult state, is much shorter than his other toes, and projects from the side of his foot at an angle resembling in this respect the great-toe or thumb on the feet of apes. Now, all the likenesses between man and the lower animals which we have pointed out are facts which are capable of demonstration, and have been verified again and again by men skilled in the various departments of investigation. What interpretation are we to put upon them? Do they mean nothing, and has man been created at once as we know him, fully developed in every way from the first, and quite distinct from every other living thing? Is it not more reasonable to suppose that they indicate a great plan of evolution and connection from the lowest to the highest? It is quite true that no remains of man's progenitors have been found connecting him in the far-distant past with the lower animals; but this is not to be wondered at when we consider that the place of his origin was in all probability the vast upland plains of Asia, which have never yet been explored by the geologist. There is no doubt such an idea of man's origin is so contrary to all our preconceived notions that we have great difficulty in receiving it, but the probability, at any rate, of its truth is very great indeed. It may be that hitherto we have judged the work of creation by our own standard. When we wish to form any object, we simply take a piece of wood or other material and carve it out at once to the required form; and we imagine the Creator has pursued the same method, and in this we may be mistaken, and are only now beginning to find out how much grander a method He has adopted. The savage, whose only plan of forming a boat is to cut down a tree, hollow it out and chip it into shape, might think we followed the same device, and be greatly astonished when told that we first laid the keel, then built the ribs, and afterwards nailed on the planks and fastened down the deck. Another objection to the theory of evolution, at least as applied to man, is a sentimental one. It is said to be degrading to imagine that man's ancestor was one of the lower animals. Now, whatever truth there may be in this, it is surely not more degrading to consider that man's progenitor may have been a four-footed animal with a tail than to know that every man, woman, and child on this earth was, at one stage of his or her existence, an animal of such a low form that it could not be distinguished from a puppy-dog or a young ape at the same stage. We might, indeed, contemplate our remote and lowly ancestor of, say, a million years ago with equanimity or indifference; but we can hardly ignore our own early being. To all who hold that the theory of man's evolution is degrading, we would commend the words addressed to the Apostle Peter when his Jewish prejudices were outraged by the command to slay and eat unclean animals—"What God hath cleansed, that call thou not common," or unclean.

ORIGIN OF MAN'S HIGHER NATURE.

ALTHOUGH the origin and development of man considered as a mere animal may be due to a process of evolution of the same nature as that which has almost been proved to a demonstration in the case of the lower animals, it does not necessarily follow that natural selection accounts for all his attributes. There may be other agencies at work, and, indeed, his exceptionally high mental and moral endowments would seem to demand such, as they separate him by an immense distance from all inferior creatures. It may be wise, at any rate, to keep our minds unbiassed, and ready to receive any more satisfactory explanation of the matter than evolution by natural selection affords. Mr. A. R. Wallace, who occupies a position scarcely inferior to Darwin himself as a naturalist, while fully endorsing the latter's views as to the evolution of man, so far as his animal nature is concerned, contends that natural selection does not account for the development of man's higher nature, and, therefore, some other cause must be looked for. A short account of Mr. Wallace's views on the subject may not be uninteresting. As we pointed out in a former article, natural selection can only preserve and develop qualities or forms which give the organisms which possess them some advantage in the great struggle for existence which is continually going on. If these qualities or forms give their possessors no such advantage, and yet develop, then they cannot be due to natural selection Now, Mr. Wallace maintains that many of man's mental qualities are of this nature, and must, therefore, be due to some agency working along with natural selection, and appearing only at a certain stage of development and making no abrupt change in continuity. He illustrates his position as follows :—" Upheaval and depression of land, combined with sub-aerial denudation by wind and frost, rain and river, and marine denudation on coast-lines, were long thought to account for all the modelling of the earth's surface not directly due to volcanic action, and in the early editions of Lyell's 'Principles of Geology' these are the sole causes appealed to. But when the action of glaciers was studied, and the recent occurrence of a glacial epoch demonstrated as a fact, many phenomena, such as moraines and other glacial deposits, boulder clay, erratic boulders, grooved and rounded rocks, and Alpine lake-basins, were seen to be due to this altogether distinct cause. There was no break of continuity, no sudden catastrophe; the cold period came on, and passed away in a most gradual manner, and its effects often passed insensibly into those produced by denudation or upheavals; yet none the less a new agency appeared at a definite time, and new effects were produced, which, though continuous with preceding effects, were not due to the same cause." According to this view, then, man was originated and developed to a certain extent by natural selection in the ordinary way, but when he reached a particular stage—say, in order to fix our ideas, when his brain organ was sufficiently complex—a new agent commenced to operate upon him, slowly at first and making very little change, but gradually increasing in power until the climax of mental and moral development was reached, and all the time this new agent did not supersede natural selection, but worked, as it were, along with it. There does not seem to be anything impossible or even improbable in this, as it is not to be supposed that, having recognised the action of natural selection, we have discovered the whole secret of life. It is a question, therefore, of sufficient proof. Mr. Wallace first draws attention to the mathematical faculty, which is almost entirely absent in low savage races. Some of them cannot count beyond two; others manage to go the length of five by using the fingers, and by adding the toes make up ten, and so on in a very elementary fashion. It is difficult for us to imagine such a state of mind as one savage exhibited who sold two sheep for two sticks of tobacco each, but did not understand that he was properly paid when four sticks of tobacco were handed to him and the two sheep taken away. He insisted that a longer process should be gone through. First two sticks had to be given to him, and then he gave up one sheep; and then other two sticks were given in exchange for the other sheep. That two and two make four was evidently beyond his comprehension. Then, again, even among the higher races of antiquity, such as the Greeks, Romans, Jews, &c., although their powers of counting were very greatly beyond those of savage races, yet their systems of notation were so cumbrous that no very great progress was possible in mathematical science except in geometry. Algebra was first introduced into Europe about the thirteenth century, and it is only within the last three centuries that mathematical science has really made remarkable progress. Considering these facts, Mr. Wallace says:—"Either prehistoric and savage races did not possess this faculty at all, or they did possess it, but had neither the means nor the incitements for its exercise. In the former case we have to ask by what means has the faculty been so rapidly developed in all civilised races, many of which a few centuries back were, in this respect, almost savages themselves; while in the latter case the difficulty is still greater, for we have to assume the existence of a faculty which had never been used either by the supposed possessors of it or by their ancestors."

Suppose that savages possessed the merest rudiments of this faculty shown by their ability to count up to five or ten, how could such a faculty be so rapidly developed as we find it in such men as Newton, La Place, &c.? Natural selection does not seem at all suited for this purpose, for it avails itself of slight variations, giving some advantage in the struggle for existence, and we can understand how it might pick out and preserve individuals whose muscles or bones or courage were slightly greater than those of their neighbours, but what advantage would it be to a savage in his fight with his enemy or with wild animals that he was able to reckon up to fifteen, while his enemy could only count ten or nothing at all? Natural selection only improves a race according to its necessities in a life-and-death struggle, and how could a slight improvement in the mathematical faculty aid in preserving the life of its possessor? The barbarous followers of Genghis Khan and other Eastern conquerors did not owe their success in the least degree to their mathematical powers; and the Romans, who possessed this faculty in some degree, were finally overcome by uncivilised races, in whom this faculty was not at all developed. The peoples who now lead the van of civilisation, and who have proved themselves the fittest to survive, did not attain their position by their high mathematical powers, although since they have attained their present position they have developed these in a most remarkable degree. Again, natural selection, from its very nature, will develop characters common to all individuals of a species which will not vary very greatly from a certain standard. Thus, if we take height in man as an example, we shall find that this may vary from perhaps four to six feet or thereabout. In speed of running, bodily strength, acuteness of vision, &c., there is no very great disparity among savage races; but when we consider the developed faculties of civilised men, the case is very different indeed. Thus, if we take the mathematical faculty, probably fewer than one in a hundred really possess it; and if we attempt to measure the amount of variation between a first-class mathematician and the ordinary run of people, it is probable that the mathematical faculty in the former could not be estimated at less than a hundred times that in the latter, and it might be put down at a much higher figure. Comparing this with the variations in height which, as we have seen, range between four and six, it would represent a variation between four and four hundred. This method of stating the case is very startling, as there is nothing analogous to it in any other department of life which is admitted to be under the control of natural selection. Mr. Wallace examines in the same manner the artistic and musical faculties, and comes to very much the same conclusions regarding them, and argues that they could not possibly have arisen and attained their present state of development through a process of evolution due to natural selection. Analogous to these he classes the metaphysical faculties, which enable us to form abstract conceptions of things, to discuss ultimate causes, the nature and qualities of matter, motion, will, conscience, &c., all of which are incomprehensible to savages, who seem to have no mental faculty enabling them to grasp such conceptions. Yet when any race becomes somewhat civilised, and has leisure to devote itself to the consideration of such subjects, this metaphysical faculty seems to start suddenly into existence. If, then, there are certain mental faculties which either do not exist at all or exist only in a very rudimentary form among low and savage races, but which suddenly appear in almost perfect development among the higher races; and, further, if these faculties are distinguished by their sporadic character, being well developed in only a few individuals of a community, and by the enormous amount of variation in their development, then they are quite inconsistent with any action of natural selection which may have produced the ordinary animal characteristics of man, and must be due to some altogether different agent, and not derived from his animal progenitors. This agent Mr. Wallace considers to be of a spiritual nature, and is superadded to man's ordinary animal nature, and is capable of development under favourable circumstances. On such a supposition many things are made plain which would otherwise be unintelligible, such as the influence of ideas, principles, and beliefs on man's actions and life generally. Such is a brief account of Mr. Wallace's views, and although they may be entirely rejected by the extreme school of evolutionists, and although even more moderate men may not be able altogether to agree with him, yet they are well worthy of careful attention, coming as they do from such a high authority on the subject. They, at any rate, make it quite evident that although man may be derived by evolution from the lower animals, yet he may at the same time be endowed with a higher nature derived from a perfectly different source. We need not, therefore, consider ourselves as only highly developed animals, but may still, even if evolution be true, cherish our beliefs and aspirations, and hopes of a much higher destiny than awaits the brutes which perish.

ANTIQUITY OF MAN.

It is not many years since it was almost universally believed that man made his first appearance on the earth about six thousand years ago, but modern research has proved that this belief, like a great many others, is not well founded, and is inconsistent with observed facts. The records of Egypt, China, &c., show that empires existed in a high state of civilisation thousands of years before the Christian era, and, if we allow the time necessary for their full development, must have been founded long before the supposed time of man's advent. By the researches of geologists, also, it has been found that man existed spread over many widely separated regions of the earth ages before any historical records existed. The evidences of this fact have been slowly and laboriously accumulated, and have not been accepted without rigid scrutiny, and much opposition and controversy. It has, nevertheless, been made quite evident that although the date of man's first appearance cannot be definitely fixed, yet it must be put back not only thousands but tens of thousands of years before that which had formerly been accepted. We shall very briefly give an account of the discoveries which have led to this conclusion.

In many countries there are vast masses of peat formed in great part from mosses which have grown and decayed year after year in the same place, and the organic remains of which have accumulated during long ages. In Denmark these peat mosses, as they are called, have been very carefully examined, and have revealed a long and interesting story of man and his works. That they carry us back thousands of years in the earth's history is very evident, even if we only consider their depth, which varies from ten to thirty feet, and the slow rate at which the mosses are deposited. This, however, becomes more and more apparent as we study the remains which they contain. At various depths in the peat, trunks of trees, sometimes of large size, are found, which must have grown on the margin of the ancient swamps and fallen among the mosses as they grew. In the lower parts of the peat moss these trees are generally Scottish firs, a species which is not now found in Denmark, and which does not thrive in that country when artificially planted there. A little higher up these firs disappear, and their place is taken by a species of oak which is not now generally found in Denmark. Many other varieties of trees are found, some of which still exist in the country, while others do not; but the whole arrangement indicates a long period, during which there were considerable alterations of climate, causing one species of tree after another to flourish, and then to become extinct when its place was taken by another. Now, in these peat mosses, associated with the remains of these trees, we find implements of various kinds—knives, hatchets, axes, &c.—evidently of human manufacture, all telling the same story of long time and gradual development. Generally speaking, in the lower parts, where the fir is abundant, the implements are of stone. Higher up in the strata, where the oak is found, the implements are of bronze, and on the top of all, and therefore most recent, they are formed of iron. Owing to this arrangement, geologists speak of a stone, bronze, and iron age following one another in succession in these regions.

In addition to these peat mosses there are other accumulations of a different nature which give evidence of the great antiquity of man. These are refuse-heaps or mounds of castaway shells of oysters, cockles, &c., mixed with bones of various kinds of animals used as food for man. These mounds in some cases are of enormous size, being from three to ten feet thick, with a length of a thousand feet and breadth of one hundred and fifty to two hundred feet, and point to a long period during which man inhabited these regions. Among the proofs of this may be mentioned the fact that the shells of the oysters are of a large size, similar to those found in the open sea, while those which inhabit the Baltic at the present time are much smaller and altogether inferior, as this mollusc cannot thrive in the brackish waters of that sea. Therefore, during the long ages in which these ancient men lived the Baltic must have had a freer connection with the ocean, so that plenty of salt water might enter; the arrangement of land and sea must have been very different from what now obtains in these regions. All through these refuse-heaps are found implements of flint, horn, wood, and bone, and also coarse pottery, but not implements of bronze or iron, showing that they belong rather to the stone age than to those of bronze and iron. Although both the peat mosses and the refuse-heaps have been most thoroughly investigated in Denmark, they are found in other countries as well, our own included, showing that even in these early times man was widely spread over the world. In Switzerland some very curious discoveries have been made, which throw considerable light on the habits and modes of living of these prehistoric men. In many of the lakes, where the water is not very deep, there are found remains of ancient wooden piles which have evidently once supported villages of considerable extent. It has been estimated that some of them may have contained a population of a thousand persons. No doubt this peculiar situation was chosen as a protection from wild animals and from human enemies. In these remains are found a variety of interesting articles, such as carbonised wheat, cakes of bread, bones of animals, as well as implements of stone and bronze.

It has to be noticed, however, that in all the cases we have referred to the animal remains are those of species which still exist; none of them are extinct, and although we are carried back thousands of years, yet the date is comparatively modern. It is very different with those we have now to mention. In the year 1828 some discoveries made in the south of France seemed to throw a new light on the subject of the antiquity of man. In that year, in the cavern of Bize, in the department of the Aube, there were found human bones and teeth, together with some fragments of rude pottery in mud firmly cemented in a mass by lime; and mixed up with the human remains were land shells of living species and the bones of mammalia, some of recent and some of extinct species; and it was pointed out that these remains could not have been washed in by some diluvial catastrophe or flood, but must have been gradually introduced together with the mud and pebbles at successive periods. Similar remains were found at another cavern, near Nismes, associated with bones of an extinct hyæna and rhinoceros. Now, the importance of these discoveries lay in the fact that human remains were found mixed with those of extinct species of animals, and if it could be proved that man really lived at the same period as these extinct animals, it would manifestly carry the date of his appearance very much farther back in the world's history than had hitherto been proved. Great doubts were at first entertained as to this, and many scientific men maintained that the remains must have been accidentally mixed. Some years later a careful examination of some forty caverns in the valleys of the Meuse was made by Dr. Schmerling, of Liége. In many of them he found the floors were encrusted with unbroken stalagmite or hardened limestone, and underneath he found human bones so rolled and scattered as to preclude all idea of their having been buried on the spot, and intimately associated with them were bones of many extinct animals, such as the cave bear, hyæna, elephant, &c., and all had the same appearance of having been buried about the same time. There were no indications of the caves having been used as dens for wild beasts, and he therefore concluded that all the contents had been swept in by streams communicating with the surface of the ground, and had no hesitation in affirming that man lived in these districts at the same time as those extinct mammalia. Many other caves were explored in different regions, and all with the same result; so that the element of chance mixing was out of the question. The same phenomena could not possibly happen so invariably in different parts of the earth by mere chance. Now, the position of these caves, as well as their contents, shows that ages must have elapsed since they were filled, because many of them are situated on the faces of perpendicular precipices of two hundred feet high or so, at which level rivers must at one time have flowed, and carried the remains into the caves. The great valleys in which the rivers now flow have been gradually excavated since; and the time necessary for this must have been enormous.

After these cave deposits had been discovered it was argued that, if man really existed during these remote periods, traces of his presence ought to be found more widely scattered than in isolated caves, and very soon this additional evidence was found. In many parts of Europe there are accumulations of sand, gravel, &c., situated on the sides of valleys very considerably above the level of present rivers; but from the remains which they contain it is evident that they mark old channels, and have been deposited from running water. These old channels are now high and dry; the streams have taken other courses or cut their way down to lower levels, widening and deepening the valleys in their courses. Now, in these accumulations, in addition to fresh-water shells, there are found bones of both living and extinct species of animals very similar to those in the caves we have described; and in 1841 M. Bourcher de Perthes first discovered, in the valley of the Somme, mixed up with these animal remains, a number of rude and primitive-looking flint implements, evidently, however, of human workmanship. He found them at various depths, often twenty to thirty feet from the surface of the ground, in beds of undisturbed sand and gravel. From geological considerations, which we cannot enter upon here, it seems certain that these deposits are of immense age, even compared with the peat formations and refuse-heaps of Denmark, as great and extensive changes have taken place in the relative distribution of land and sea, and in the configuration of the country, since they were laid down. In fact, they date back, in all probability, to those remote times when a glacial climate prevailed and Europe was covered with an ice-sheet. If, then, the flint implements found are really the works of man, of which there can be no reasonable doubt, the conclusion is inevitable that he has been an inhabitant of the earth for ages before the earliest history commenced. What may be the exact number of years cannot be definitely settled, but from astronomical considerations connected with the glacial period, as well as geological evidence, it can scarcely be much less than a hundred thousand years, and may be more. While, therefore, the comparatively recent remains in peat mosses, refuse-heaps, aud lake dwellings make it certain that man dwelt on the earth long before the historic period, the far older relics found in caves and in the river sand and gravel render it highly probable, at any rate, that he lived a hundred thousand years ago at least.

PRIMEVAL MAN.

WHETHER primeval man was a savage or civilised being is a question of considerable interest, and has often been debated in past times; but it is now pretty generally admitted that all the evidence collected points to the former condition as the true one, and leads to the conclusion that man has gradually risen to his present position from a state of barbarism. Of course, no written records can be expected to be found, even had they ever existed, in these old deposits where the earliest indications of man's existence have been discovered; but there are remains of his handiwork which tell his story, in a fragmentary and uncertain manner it is true, but still with clearness sufficient to enable us to picture his social condition and intellectual status with a considerable degree of certainty; and these all indicate a savage life continued through long periods of time without any great advance in the arts of civilised life. In gravel accumulations, and in caves which probably date as far back as the end of the glacial period, many of the implements which he used have been found, and these are all of the simplest kind, made from bits of flint rudely chipped into the forms of spear or arrow heads, hammers, saws, &c., to assist in his struggles with the wild animals, which disputed with him the possession of the forests and plains of the old world. In addition to these, there are needles, awls, and harpoons formed from horns and bones of animals, with which he put together his rough garments of skins, or captured spoil from the ocean around him. There is not the least evidence that he ever cultivated the ground or kept domestic animals. Even with the manufacture of pottery he had no acquaintance. He was a wild hunter, who lived and clothed himself by the spoils of the chase.

In regard to his dwelling-place, he had no settled habitation. For the most part the clefts in the rock served him for shelter, and in some of the old caves of England, France, &c., his remains are found mixed up with those of the animals which he killed and ate. Even the charred relics of his fires remain to this day surrounded by split bones, from which he had extracted the luscious marrow, and other records of his barbarous feasts. These have been sealed up for ages by a hard incrustation of limestone, and are only now revealed to the inquiring spirit of modern research. In these times man may have occasionally built for himself rude huts or snow-houses in the colder periods, but of these we have no evidence. We must look upon him as a dweller in caves, clothed in rough garments, and subsisting on what he could kill with the aid of his sharpened stones and other simple and primitive weapons.

This primeval man, however, had one accomplishment which may seem rather remarkable. He was an excellent artist, and must have been a close observer of natural objects. On many of his implements of bone, horn, and stone there are scratched, evidently with some sharp-pointed instruments, pictures of many of the animals with which he came into contact. These likenesses are remarkably true to nature, and can be identified at once. Thus, we have the reindeer repeatedly drawn, and even shaded, almost exactly as an artist would do it now. The cave bear is also equally well represented. Their weapons also are often curiously carved into the forms of a deer, a horse, or other animals. We find figures of the ox, the Irish elk, the bison, and also such extinct species as the mammoth or woolly elephant. This latter is valuable as showing that man really existed at the time these now extinct species lived. It is possible that the men who made these sketches existed at a later period than those who formed the rudest of the stone implements, but we cannot be certain of this, as it may have only been a sort of tribal distinction; one having the artistic sense more highly developed than the other. It may not be very flattering to artists to know that men may be skilful in sketching and yet be very low in the scale of humanity; but yet it is true; for even in modern times the Eskimo, who are savages of a low type, cover their bone implements with sketches representing hunting scenes, houses, boats, reindeer and other animals, just as these primeval men did, so that the ability to draw does not necessarily indicate an advanced state of civilisation in other departments.

Whether these old-world men had any social organisation or religious belief cannot be definitely made out. Some have supposed that there are traces of the existence of chiefs, and also of the existence of some sort of superstition connected with the ornaments which they wore, but the evidence is too slight to justify any certain conclusion. From various marks and bruises on human bones, however, it seems pretty clear that men, even at this early stage of their being, had learned the arts of war, and from this we may infer that there was some sort of order and arrangement amongst them. As to the personal appearance of these primeval men not much can be said. They have left many relics of their works, but not of themselves. It would have been most interesting if some of these ancient artists had taken to "portrait painting," and sketched or scratched men instead of animals. A portrait taken at the time of a man who lived perhaps a hundred thousand years ago, arrayed in his garments of undressed skins, with unkempt hair, and accoutred for war or the chase, would be a treasure above all price; but none such has ever yet been found, so we must endeavour to picture him to our minds as best we may by the aid of such remains as we find. In several districts human skeletons, skulls, and bones of different kinds have been discovered from time to time. Thus, in a limestone cave in the Neanderthal part of a skull was found which indicated a man of a very low type, something approaching to an ape; while at Liége another was picked up which was very well formed indeed, and there was no evidence to show that the former belonged to an earlier and less developed race. The complete skeleton of a man was also found near Mentone, and several others more or less complete in different parts of Europe. The characters of these remains are so different that it is very difficult to form from them an idea of what the primeval man was like. According to the best authorities, however, there seem to have been two races of men in these ancient times. One, probably the first to appear, had a most savage and repulsive aspect, with a low, narrow, and retreating forehead, the bones greatly developed over the eyes, the nose large and the nostrils wide, the upper jaw projected, while the chin retreated. In height this race was about five feet six or eight inches, and was strongly made. In fact, very formidable and savage both in looks and strength. The second race was quite different from this, and might be taken as a type of the "noble savage." This race was tall, handsome, and strong. According to the measurements of some bones, the average height must have been about five feet ten inches, in some cases reaching even six feet. The skull was finely arched and well proportioned, the upper part of the face broad and having no trace of the bony thickening over the eyes, the nose was high, and the mouth and chin projected well forward. It may be some consolation to artists to know that it is only among this latter race that the sketches we have referred to are found. There may have been time for the former race to develop into the latter during the long ages that the deposits in which the remains are found were accumulated, but there is no evidence that this is the fact. In truth, the two races may have existed at the same time for aught that appears to the contrary.

The Europe which these ancient men inhabited was not the Europe of to-day. In their time the British Isles were one and united to the Continent. Italy and Spain were united to Africa, and the climate was such that both tropical animals, like the lion and the hippopotamus, the elephant and the hyæna, and Arctic forms like the reindeer and the musk-sheep, were able to roam in its forests. Probably man saw many changes in this respect; from cold to warm and back again. He may have existed when the last great ice-sheet came down from the north and covered nearly the whole of what is now called Europe. Indeed, there is reason for supposing that this was the last great scene of his life, and that the ice-sheet fell like a curtain upon him and his works; for traces of primeval man come to a sudden and abrupt close. He seems to have disappeared almost at once, and nothing further is seen of him for many ages afterwards. What became of him during the long interval is not known. Whether he was entirely destroyed by the great catastrophe, or whether he merely migrated southwards to a more genial clime, and then returned when the cold had passed away, cannot be determined. One thing only is sure: he suddenly disappeared, and never returned again the same as he was. When, after the lapse of many thousands of years, man is again found in Europe, he seems to be of quite a different race. He no longer possesses the artistic qualities of his predecessor, but in other respects he seems much more developed, and civilised after a fashion. His weapons and implements are still formed of stone, but their form and finish are much superior in every respect. He seems much more capable of improvement than the primeval man; for, while the latter advances but little during long ages, the former in a comparatively short time makes great improvements. He is not content with caves for shelter, but makes for himself houses both on land and water. He grows corn and gathers domestic animals around him. In the course of time he discovers metals and substitutes first bronze, and then iron, for the stone implements of his earlier days, and at last merges into the modern man with his fully developed intellect and mechanical skill. It may be that future discoveries will fill up the gap and connect in an unbroken chain primeval man with his more modern representative, but at present there is a great blank in the history which we have no means of filling up.

ANCIENT LAKE DWELLINGS.

Among the many traces which man has left of his existence in long-past ages on the face of the earth, none are more interesting and instructive than the lake dwellings of Switzerland and other countries which have been discovered within the last fifty years or so. Although these relics of the past are far more modern than those to which we referred in the last chapter on "Primeval Man," and are probably included within the range of Egyptian and other chronologies, yet they stretch far beyond the historic period, so far as Europe is concerned, and throw a flood of light on the habits of our ancestors, or at any rate predecessors, in these regions. We are tolerably well acquainted with the history of the Jews when David worked his way up from the shepherd's staff to the royal sceptre, or when Joshua drove out the Canaanites and took possession of their land, but of what was going on in Europe in these times we have hitherto had no knowledge whatever. These lake dwellings, however, were in all probability inhabited by human beings somewhere about the time when the events we have referred to took place, and may have been inhabited before the earlier of them.

The first hint we had of the existence of these remarkable dwellings was obtained in 1829, when an excavation was being made on the shore of a Swiss lake. Some wooden piles, apparently very old, and other antiquities were found by the workmen. Not much attention, however, was paid to this discovery till 1854, when a Mr. Aeppli drew attention to some remains of human handiwork found near his house, in part of the bed of a lake which had been left dry during a season of great drought. The workmen employed in recovering some land from the lake found the heads of a great many wooden piles protruding through the mud, and also a number of stags' horns and implements of various descriptions. Stimulated by this discovery, search was made in various lakes, and the result was truly astonishing. In every direction remains of the habitations of prehistoric man were discovered, and relics were found in such abundance that the history of this unknown past could be traced through long ages, and the habits of the people ascertained with a very considerable amount of probability. The details are so numerous and interesting that more than one chapter might be devoted to them, but we shall only give a very general outline at present.

Of course, during the long time that has elapsed since these structures were erected, their remains have been reduced to mere ruins, and it is only by comparing one with another that we are able to picture to ourselves what they were originally like and what sort of life was led by the men who inhabited them. The oldest of these dwellings belong to the stone age, when man had not acquired any knowledge of the use of metals; when all his implements were merely sharpened stones fixed in wooden handles, or pieces of bone, horn, or other natural material. They are therefore somewhat roughly finished, but at the same time exhibit considerable ingenuity and skill. The method of construction seems to have been somewhat as follows :—A suitable situation, not far from the shore, where the water was not very deep, having been fixed upon, these prehistoric builders drove into the muddy bottom of the lake a number of piles or long stakes, arranged generally pretty close together, and in some sort of regular order. These piles were formed generally from stems of trees, with the bark on, but occasionally from split wood. The ends were sharpened to a point by the aid of fire or by cutting with stone axes. On a sufficient number being driven in, and their upper ends brought to a level above the surface of the water, platform beams were laid across, fastened by wooden pegs, or in some cases fixed into notches cut in the heads of the vertical piles. The platform was generally very roughly made—just a series of unbarked stems placed side by side and covered with layers of earth or clay, with numerous openings through which refuse of all kinds fell into the water beneath. In many cases connection with the shore was made by means of a narrow bridge or gangway, constructed in the same manner. On this rude platform huts were erected by driving small piles or stakes which projected above the floor, and to these were fastened boards standing edgeways like the skirting of our ordinary rooms, and marking out the size of each building. The walls of the huts were formed of small branches of twigs interwoven and plastered over with clay. The roof was made of straw or reeds, like a thatched cottage. In size these huts were probably eighteen to twenty feet long, eight or ten feet broad, and about six feet high. They may have been divided into rooms, but there is no evidence of this. Each was provided with a hearth formed of three or four slabs of stone. The number of huts in each settlement must have been considerable; in fact, they must have formed villages of no mean extent; as many as forty, fifty, or even a hundred thousand piles have been found spread over a large extent of ground, forming the foundation of one such settlement. It is probable, however, that these were not so numerous when first erected, but were gradually added to as the population increased. This fact, along with many others, shows that these dwellings were inhabited for long periods of time, during which the population pursued their ordinary life in comparative peace and quietness in their island homes.

Such is, in brief, a general account of these remarkable structures. Of course, there were several variations in the methods of fixing these piles, one of which may be mentioned as showing the ingenuity of the builders. Where the piles did not get a firm hold of the lake bottom, they carried out in boats or rafts loads of stones, which they threw down between the piles, thus firmly fixing them, just as modern engineers sometimes do for a similar purpose. As to the habits of the people who dwelt in these lake dwellings, we get a considerable amount of information from the various implements, refuse, &c., which fell through the imperfectly closed platforms into the lake, and which have been preserved in the mud at the bottom. They were fishers, hunters, shepherds, and agriculturists. Skeletons of fish are found in large abundance, and in some settlements even the fishing-nets and hooks made of boars' tusks have been discovered. Then, again, there is an abundance of remains of the hunter's feast; bones of the stag, wild boar, bear, wolf, otter, squirrel, and many other wild animals are found in rich profusion, and often these are split and the marrow extracted. These ancient men, however, did not entirely rely on such precarious provision for their wants, but were so far advanced in civilisation that they kept cattle and domestic animals of various kinds. They possessed dogs in great numbers, as well as cows, sheep, goats, and pigs, and in winter-time had these housed on their settlements, as among the remains found are litters of straw, &c., which had evidently served as bedding for these animals. This, of course, necessitated the gathering of grass or other material for their food. They also cultivated wheat, barley, flax, and a number of other vegetable products. Their methods of cultivation were no doubt very rude, consisting of a mere scratching of the ground with crooked branches of trees or with simple implements made of stags' horns; but, nevertheless, they succeeded in getting very good results. Among the relics which they have left are found stones for crushing corn, the grain which they used, and even the very cakes or bread which they made. There are also fruits, such as the apple, pear, nut, &c.; so that the bill of fare of prehistoric man was by no means contemptible. He had fish, game, beef, mutton, pork, bread, and fruit, besides a plentiful supply of water from the lake at his door. He was acquainted with the potter's art, and manufactured earthen vessels of various kinds. He seems to have produced two kinds—a coarser and a finer; the former made from clay mixed with a quantity of grains of stone, and the latter of washed loam. These he ornamented in an elementary fashion with certain lines and marks. Some of the vessels he used have been found with a burnt crust of the porridge which he had been making adhering. As to his clothes, these were probably formed in great part from the skins of wild or domestic animals, but he also used fabrics made from flax, which he had learned to weave, as remains of cloth, twine, rope, &c., are not infrequently found in his dwellings.

One prominent feature in the history of these lake dwellers is their gradual advance in the arts of civilisation. While the main features of their settlements remain very much the same during the whole period of their residence, there is a gradual improvement in the details; the settlements become larger, and the implements, &c., better finished. And this is especially observable in the change of material which the dweller uses. In the earlier stages of his existence stone is the predominant feature—all his knives, saws, chisels, axes, &c., are made from this substance; but as time rolls on, one or two implements are found made of bronze, which is a mixture of tin and copper, and requires for its production a certain amount of knowledge and mechanical skill. Gradually the number of bronze implements increases until eventually stone is superseded altogether, and improved forms of weapons of war make their appearance, and his work has a more finished look, arising from his improved implements. Whether the manufacture of bronze was an original discovery of his own, or whether it was an importation from some more advanced race, is not certainly known; but as he undoubtedly had intercourse with the East, it is probable that the first bronze was imported, and that afterwards he discovered the way to manufacture it himself. However this may be, it seems evident that the introduction of this material greatly aided his development. As stone gave place to bronze, so in the course of time this latter gave place to iron, probably introduced in the same manner some considerable time before the dawn of history; and this metal held its place until these habitations were finally abandoned.

With regard to the religion of these lake dwellers, if they had any, nothing is known. From some curious objects formed somewhat like the crescent of the moon, which are found in considerable numbers, it has been supposed that they worshipped that body; but there seems to be really no evidence for this supposition, and these objects may only have been ornaments, or perhaps charms, fixed above the doors of their huts, something after the manner of the horse-shoe nailed over the door in modern times to keep away evil spirits. So far as can be inferred from the remains that have been examined, the same race seems to have inhabited these dwellings from their commencement to their end. There is no appearance of invasion from without; all seems continuous. Probably this race came in early time from the East, and was a pastoral people, with flocks, herds, and domestic animals, and built their peculiar habitations to protect themselves from human enemies. Certainly the arrangements were well fitted for the purpose in those days, when the club and the spear were almost the only weapons of offence. Dr. Keller, who has investigated this subject with great care, is of the opinion that these lake dwellers were a branch of the great Celtic race.

II.

PROTOPLASM.

ORIGIN OF LIFE.

The origin of life is a subject of great speculative interest, and our mental vision would be greatly enlarged if by any means we could obtain a knowledge of it. This knowledge, also, would be of practical importance; for, as we shall show in the chapter on "Disease Germs," many virulent diseases are due to the existence of minute living organisms; and it is very necessary, therefore, that we should know, if possible, how these arise—whether they come from without, or whether they are formed from within out of the decayed or dead matter of our bodies, or from the original inorganic elements themselves. Manifestly our treatment of these diseases must largely depend on the answer we can give to these questions. In short, we wish to know if life arises from the mutual actions of inorganic elements or dead matter through some property inherent in these elements, or if in all cases living things only arise from pre-existing life. Now, it does not seem at all impossible that life may arise from the inorganic elements, for these are possessed of wonderful powers apparently very much like those of actual living things. Thus, crystals grow by adding particle to particle in a very remarkable manner, and beautiful structures are formed in suitable media; and we have such substances as camphor in water giving rise to movements which have very much the appearance of living action. May not, then, the maggots in dead meat, or the mites in cheese, arise anew from the lifeless substances? Further, the doctrine of evolution, so generally received, would seem to require the passage of dead inorganic elements into forms of life in order to make it complete; for, according to that doctrine, all life is supposed to originate from some primordial form or forms, and it would seem in keeping to trace this origin still farther back to the inorganic elements themselves, for how otherwise could life have arisen? Tyndall, in his Belfast address to the British Association, said something to the effect that in the use of our scientific imaginations we may consider that in a whiff of cosmical vapour there is the promise and potency of all future life; but as that vapour has, so far as we can judge, to pass through a period of intense heat before it becomes the seat of life, and as that heat would certainly destroy every living germ, we should expect the potency to remain in the inorganic elements which survive the ordeal in order that life may spring up when the conditions become favourable.

It is not surprising, therefore, that, while this question has attracted the attention of learned men from the earliest times, it should have been assumed that dead matter could of itself give rise to various forms of life. Thus, Aristotle says, "All dry bodies which have become damp, and all damp bodies which are dried, engender animal life;" and a certain doctor, Van Helmont, while declaring that the smells from morasses produce all sorts of living things, such as slugs, frogs, leeches, &c., actually gives a recipe for the production of a pot of mice. All we have to do, he says, is to press a dirty shirt into the orifice of a vessel containing a little corn, and after about twenty-one days the ferment proceeding from the dirty shirt, modified by the odour of the corn, effects the transformation of the wheat into full-grown mice. We may smile at the simplicity of such experiments and the credulity of the experimenters; but we must remember that science in its modern aspect had no existence in those days, and the crudest results were accepted as veritable facts. An Italian naturalist named Redi was, apparently, the first who took up the subject in a scientific manner, and threw doubts on these early ideas. He observed that maggots in meat were not spontaneously developed, but were due to the flies, which were continually buzzing about, depositing eggs in the interior of the flesh, where they were hatched and developed into maggots. He showed this in a very simple manner; he merely placed a fine wire gauze over the meat so that the flies could not get near, and when he did so he found that, although, after some time, the meat became putrid, no maggots were seen, but these were found on the surface of the wire gauze where the flies had deposited their eggs. This discovery of Redi's did much to destroy the belief in spontaneous development of life, at least in the case of these comparatively high forms; but it was by no means extinct, and when the microscope came into use, and revealed a world of unsuspected wonders in minute forms of life, the belief revived and recovered strength. It was said by many eminent men that the higher forms of life are only derived from parents of the same kind, but these lowly forms which we now see revealed to us are certainly the production of dead matter. Do these little bits of protoplasm not owe their origin to the mutual affinities of the atoms of carbon, nitrogen, &c., of which they are built up, just as crystals are built up owing to the affinities of their elements?

The controversy which arose on this subject was carried on with great vigour on both sides, some maintaining that even these minute organisms were produced from spores which are widely distributed ready to take root whenever a suitable soil was found, while others declared that they were produced afresh in substances which were entirely free from either the organisms themselves or their spores. Pouchet, director of the Museum at Rouen, one of the most eminent supporters of the spontaneous development theory, ridiculed the idea of spores being so widely spread, and said that to produce the known results there would have to be such numbers of them in the atmosphere that it would become as dense as iron. He prepared infusions of suitable material freed from every trace of life by thorough boiling, and introduced into the same vessel prepared oxygen gas, also free from all life-germs, and yet found life abundantly developed in the solutions, and declared that he thus demonstrated in an absolutely certain manner the existence of living organisms which had come into the world without germs or parents of any kind. For a time Pouchet seemed to beat down all opposition to his views; but the subject was beset with great difficulties, the organisms and germs that had to be observed were so infinitesimal that they might easily escape recognition and get into the solutions without being noticed; and so it seemed at one time as if the question never could be satisfactorily settled. Pasteur, however, took up the matter, and by a series of masterly experiments proved that Pouchet had neglected one precaution which entirely vitiated the whole of his results. While he had taken care to free his infusions and oxygen from all traces of life, he had neglected the surface of the mercury in which he had dipped the mouths of his glass flasks, and consequently the dust from the air collected on the surface of the mercury had passed from thence into his infusions, carrying with it those invisible germs which subsequently gave rise to the living forms which he saw. Pasteur repeated Pouchet's experiments, taking, however, precautions to avoid this source of error, and found that under these circumstances no life whatever was produced. Not content with this negative evidence, Pasteur proceeded to prove that it was really something in the air which produced the living forms. He filtered ordinary air through plugs of cotton-wool or æsbestos, after which it was quite incapable of giving rise to the organisms. Then he took the plugs of wool through which the air had passed, and carefully washed them in pure water, and on examining this water with the microscope, he found it full of minute particles of matter of various kinds, and, among these, living forms of various kinds which rapidly developed themselves and multiplied at a prodigious rate by dividing and growing. He proved by analogous means that these germs do not exist everywhere, and that it is possible to get ordinary air quite free from them on the tops of mountains and other places where the air is not likely to be polluted; and in all these places infusions, which in ordinary air developed living forms rapidly, remained perfectly pure and unaltered. It was evident, therefore, that it was not the air by itself that produced the life in the infusions, but something that the air sometimes carried with it. Again, he took an infusion of suitable material, and enclosing it in a flask, destroyed by continued boiling every germ which it contained, and then drew out the neck of the flask, and twisted it round and round several times like a corkscrew, so that the entrance to the flask was rendered narrow and tortuous. By this means any germs that might enter the mouth of the flask would be caught on the twisting sides of the passage and stick to the glass, and be prevented reaching the infusion. Infusions thus treated remained clear and free from life for weeks, months, and even years, but when the twisted neck was broken off, so that the air had free access, living organisms were rapidly produced. Further, the outsides of these flasks became covered with fine dust deposited from the atmosphere, and when he allowed a drop of the infusion to touch this dust and then to trickle back through the narrow twisted neck into the flask, the production of life was again observed.

These experiments, although so simple, carry conviction to the mind of every unprejudiced thinker. They were, however, supplemented by many others of a like nature, all pointing to the same conclusion—that no life was produced unless germs of some sort got into the infusion from without. Tyndall also made a series of experiments of the same nature, and amply confirmed all Pasteur's results, and added many original proofs of his own of the correctness of the conclusions. He showed that if infusions, which when exposed to ordinary air rapidly developed living organisms, were carried to remote mountain-tops free from all possible contamination, no life whatever was developed. He also introduced a novel method of demonstrating in a most striking manner the necessity of floating matter in the air for the production of life. He prepared a box having glass windows in the front and sides, through which he could send a strong beam of light. The track of the beam could be clearly traced by means of the dust particles floating about. In this box he had many tubes into which he introduced putrescible substances, which rapidly gave signs of life being produced. If, however, he coated the sides of the box with glycerine or other sticky substance, and allowed it to stand for two or three days, all the floating particles settled down and stuck to the sides, and the track of the beam of light was no longer visible; the air was perfectly free from dust. In these circumstances, his putrescible infusions showed no signs of life, but remained clear. Thus, without acting on the air in any way whatever except allowing it to settle quietly of itself, he rendered it incapable of engendering these living forms. That the solutions in his tubes were still susceptible of nourishing these germs he proved by letting in a little of the outside air, laden with dust as usual, when at once the cultivation was set up, and life-forms commenced to spread rapidly through the solutions. By other experiments Tyndall also proved that many of these spores or germs of minute life were exceedingly difficult to destroy, and that to get rid of them entirely in any solution continued boiling at intervals was absolutely necessary. In some instances he required to boil for eight hours to get rid of every trace of life. It was thus evident that many of the results seemingly opposed to those we have noticed which the advocates for spontaneous development brought forward were simply due to the fact that the precautions taken to exclude or destroy all germs coming from without were not sufficient.

As the result of all these investigations, continued for many years, it seems certain that, as far as can be observed, life is never produced except from a living ancestor. Not the minutest speck of living matter is ever built up from its inorganic elements except by the agency of already existing living matter. We must remember, however, that this does not mean that the thing is impossible, and that at no time or place did such a thing ever occur. The subject is still open to investigation, but so far as our knowledge goes, the origin of life is from life, and we can trace it no farther back. It may be as Sir William Thomson has suggested, that life has come to this planet from some distant source in the regions of space, but, if so, the problem is only removed a little farther off; it is not solved.

THE BASIS OF LIFE.

As the telescope enables us to penetrate the far regions of space, and to observe the first beginnings of suns and systems of worlds as they evolve from the primeval cosmic vapour, so does the microscope reveal to us the innermost constitution of organised matter, and the emerging of the various forms of life from their unorganised physical basis. Previous to the invention of these instruments, knowledge was circumscribed by a barrier which could not be broken down, viz., our inability to see; but on their introduction this barrier disappeared, and new worlds were opened to our investigation, resulting in the splendid discoveries of modern astronomy, and the no less splendid, though, perhaps, not so generally appreciated, discoveries in the minute forms of animal and vegetable life. When the microscope was applied to the examination of living tissues, it was very soon observed that all living things, animal or vegetable, were built up of small bodies or organisms, as they might be called, of essentially the same nature. These organisms have been called cells, because, generally speaking, they consist of an outside covering, enclosing semi-fluid contents, and no essential difference can be observed between those cells which form the animal and those which form the vegetable. It is only in the process of development that they are modified so as to form the different organs and structures of plant or animal. Within those cells are nuclei or central points like one cell within another, which seem to exercise considerable influence on the process of development, and in which, apparently, is the seat of their activity. The cells grow and multiply by division. Thus one divides into two, the two into four, and so on, each containing its semi-fluid contents and its central nucleus and other minute features. The cell is, therefore, regarded from this point of view as the basis of life, and the whole organism of plant or animal as the combined results of the activities of every cell which it contains.

This cell theory, as it is called, had very soon, however, to be modified, as the powers of the microscope were increased and new facts brought to light. Close observation speedily showed that the source of vital energy is not exactly in the cell itself, but in its contents. Neither the surrounding envelope nor the central nucleus is essential, as the semi-fluid viscous contents alone, in which no definite structure is apparent, are capable of exhibiting all the phenomena of life. There are certain organisms composed of what may be called a single drop of this substance which are able to move spontaneously as if actuated by some sort of will; they can alter their shapes in a most marvellous manner, they are extremely sensitive to external influence, they assimilate or consume surrounding matter, they grow and waste—in short, possess all the faculties of living things. This very rudimentary form of matter may, under certain circumstances, surround itself with an envelope or covering, develop a nucleus, and form a complete cell, so that it, rather than the cell itself, must be regarded as the fundamental unit or basis of all life; every blade of grass, every flower of the field, every animal, and even man himself, originates from a drop of this viscous fluid, and owes life and activity to its remarkable properties. From the fact that it is the first substance in organic nature from which all others are moulded, it has received the name of protoplasm.

Although, generally speaking, this protoplasm has no definite parts, or is structureless, at least as seen in ordinary microscopes, yet, when examined under the highest microscopical power, it appears as an exceedingly fine network of delicate fibres. This network is generally pretty uniform. The width of the meshes vary to some extent; sometimes they are narrow and close, and sometimes wider and more open. The inter-spaces are filled with fluid and minute particles or granules of variable size. There are some indications of different kinds of matter, but no trustworthy evidence of structure can be observed; and as there is a limit to the powers of the microscope, it is not probable that we shall ever be able to see any distinction of parts in the substance of which the network is composed. The microscope can tell us no more, but there may be, and there are, good grounds for supposing that there is structure which cannot be directly observed. We turn, therefore, to the chemical nature of this remarkable substance for further light as to the cause of its marvellous properties. Now, there is no doubt that all matter, of whatever kind, is made up of little particles or atoms so small that they are, and must ever remain, perfectly invisible to the human eye even when aided by all the appliances of optical science, and it is only when a number of these unite into one body that they become visible. Every little piece of matter, therefore, which we can see is built up of thousands, or rather millions, of these little atoms. There are many different kinds of atoms; thus we have carbon, hydrogen, oxygen, and other kinds, each having its own particular weight. A carbon atom is twelve times as heavy as one of hydrogen, and so on. It is probable, also, that they differ as to size, shape, &c. They combine together by mutual attraction, which, in some cases, we call cohesion, and in others chemical affinity, according as the atoms are of the same or different kinds. It is easy to understand, therefore, that having myriads of, as it were, small bricks of different sizes, shapes, and kinds, which combine together with varying degrees of intensity, an endless variety of structures of different degrees of stability may be built up. We may have masses of the same or different kinds of atoms, stable and solid, cohering firmly together, or we may have elaborate structures made up of many different kinds and sizes held together in a somewhat loose fashion and ready to fall to pieces on the slightest touch; and between these extremes many varieties more or less stable or unstable. Thus water, for instance, is a very stable compound; the hydrogen and oxygen atoms of which it is composed hold very firmly together, and a considerable amount of force has to be exerted to separate them. On the other hand, that dangerous explosive, terchloride of nitrogen, is a very unstable compound; the nitrogen and chlorine of which it is composed are so loosely combined that the touch of a feather causes their instantaneous separation with excessive violence.

It is, however, in the carbon or so-called organic compounds that this complexity of structure is found in its most marked form. This element carbon has the most marvellous power of combination with hydrogen, nitrogen, oxygen, and certain other substances, acting, as it were, as a sort of centre binding them all together, and the number of its compounds is so great as to necessitate a division of chemistry for itself. From its peculiar properties, it permits of arrangement of the atoms so that many of its compounds having the same number and kind of atoms in their structure, but differently arranged, exhibit quite distinct properties. Now, protoplasm is one of these carbon compounds, and is perhaps the most complex of them all. In fact, it seems to have reached the utmost limit that is possible in this respect, and the chemical equilibrium is so unstable that it is ready to break down at the least touch.

We can regard protoplasm as occupying the summit of chemical changes; the elements of food are, by their mutual affinities, gradually built up into more and more complex structures until they reach the form of protoplasm, when they can go no farther, but begin to break up under certain conditions into less and less complex forms until they reach the final stage of carbonic acid, water, &c., which all organic matter finally comes to. We have something analogous to this in the formation of crystals in a water solution. These beautiful structures are built up step by step, owing to the mutual affinities of the constituent atoms. Of course, they possess considerable stability, and do not readily break up; but they can be broken up with comparative ease by heat into water and the salt of which they are composed.

Protoplasm, then, being such an unstable compound as it is, we can readily understand its extreme sensibility to any outside stimulus. Slight changes may be brought about which cause it to alter its shape, move, and exhibit other phenomena; changes may even take place in its interior without any apparent cause. It may be thought physical changes can hardly cause motion of the protoplasm, but there are instances of this in ordinary forms of matter. Thus, if we put a little bit of camphor on the surface of still water, it runs about in apparently the most capricious manner as if it were a living thing, and yet we know this is due to what is called surface tension, which, in its turn, arises from attraction of the atoms or molecules. Of course, we do not say that the movements of protoplasm are due to the same cause, but only give this as an instance of motion of this kind being due to a purely physical cause. From these considerations it is evident that although the microscope shows us but little trace of anything like structure, yet we have considerable evidence that protoplasm is in reality one of the most complex structures in nature, and consists of many different parts, and that many of the peculiar phenomena which it exhibits are due to the inter-action of the chemical affinities of the atoms of which it is composed. We have already pointed out that protoplasm in general manifests irritability and contractility, that it assimilates the elements of food and grows thereby, and that it decays or breaks up easily; but all forms of this substance do not exhibit these characteristics in equal degrees. Some kinds of it get modified in certain ways, so that they show the contractility in greater degree, and others the assimilating power, and so on; and in the higher animals and plants this division of labour, as it may be called, is carried out to a large extent, and we have the various tissues of the body, such as nerve and muscle tissue. Thus in the water polyp or hydra we have an organism consisting, in the main, of two tubes of protoplasm, an inner and an outer one. The inner one is chiefly concerned with the assimilation of food, and elaborates it into such a form that it is easily taken up by the protoplasm of the outer tube, which is thus saved the labour of preparing its own nourishment. The inner tube exhibits very little irritability. On the other hand, the protoplasm of the outer tube is extremely irritable, and responds to any stimulus, and thus is capable of motion, while it is deficient in power of assimilation. It is evident that this sort of change of function may be extended, and we may have protoplasm adapted to any kind of special work that may be necessary. Of course, in the process of evolution organs specially adapted to the kind of action required are speedily developed; but these are rather the productions of the protoplasm by means of which it accomplishes the end in view than the causes of the action. We may conclude, then, that there must be many different kinds of protoplasm, or at least modifications, as we find that specimens of this substance existing in different beings, or in different parts of the same being, differ widely in the relative prominence given to one or other of its fundamental characters. We can conceive that this variation may be due to changes in the structural arrangements of the protoplasm, which, of course, are too minute for our observation.

BACTERIA.

In the popular mind Bacteria and other allied forms of organic nature are associated with the idea of pestilence and disease, and are looked upon as noxious things to be got rid of as speedily as possible. This idea is very natural, as undoubtedly many of these organisms are the prolific sources of much that is apparently hurtful to the human race, although it may be doubted whether their action is really so evil as it appears on the surface. At any rate, this is a very narrow and superficial view to take of the matter; for it can be readily shown that bacteria, when regarded in a general and comprehensive manner, really form an essential part of the economy of nature; and perhaps no recent advances in science have done so much to enlarge our conceptions of the grandeur and unity of nature as the knowledge we have obtained of the life and works of these minute forms. In fact, a new world has been opened up for our investigation, full of marvels undreamt of by our forefathers, and a flood of light has been cast on many problems which have hitherto resisted all our efforts to solve. The sphere of living action has been extended, and many operations which were formerly supposed to be due to the physical action of the inorganic elements are now known to be the result of the life-processes of organised beings which exist in myriads on every side of us. Hitherto we have regarded the vegetable world as directly abstracting from the soil and from the atmosphere those elements which are necessary for the sustenance of life, and building them up into compounds of more or less complexity, which in turn serve as food for the animal world, as the latter cannot directly assimilate the inorganic elements. When plants or animals died we supposed that these compounds fell to pieces of themselves, or at least when acted on by the oxygen of air, and became again those simple elements which might serve anew as the food of plants. This view is now found to be quite erroneous. If left to the forces of inorganic nature, dead matter would not thus decay and break up, and we should have an accumulation of waste material which would speedily choke up the whole living world. Animals would die and remain entire, just like those antediluvian monsters we find embedded in the polar ice. How, then, is such a state of matters averted? By what means is the continual accumulation of waste material removed? The answer to these questions is found in the work done by bacteria, ferments, and other minute forms of life. This work cannot be better described than in the words of Pasteur, the greatest authority on the subject, who says: "In the destruction of that which has lived all reduces itself to the simultaneous action of those three great natural phenomena—fermentation, putrefaction, and slow combustion. A living organism dies—animal or plant, or the remains of one or the other. It is exposed to the contact of the air. To the life which has quitted it succeeds life under other forms. In the superficial parts, which the air can reach, the germs of the infinitely small aérobies hatch and multiply themselves. The carbon, the hydrogen, and the nitrogen of the organic matters are transformed by the oxygen of the air, and under the influence of the life of these aérobies into carbonic acid, vapour of water, and ammonia gas. As long as organic matter and air are present these combustions will continue. While these superficial combustions are going on, fermentation and putrefaction are doing their work in the interior of the mass by the developed germs of the anaérobies, which not only do not require oxygen for their life, but which oxygen actually kills. Little by little at length by this work of fermentation and slow combustion the phenomenon is accomplished. Whether in the free atmosphere or under the earth, which is always more or less impregnated with air, all animal and vegetable matters end by disappearing. These facts still further strengthen all the new ideas as to the important part performed by these infinitely small organisms, which are, in fact, the masters of the world. If we could suppress their work which is always going on, the surface of the globe, encumbered with organic matters, would soon become uninhabitable." From this description we can clearly understand the important and beneficent part which these lowly forms play in the great cycle of life. They are the great regenerators; nothing is lost; whatever is useless and cumbers the ground is at once seized by these tiny workers and speedily transformed into suitable material for the nourishment of other living things. In truth, absolute death seems nowhere to be found; it is only a change of form. The same material is handed from the lower to the higher, and then back again in a ceaseless round.

For a long time the exact nature of bacteria was a subject of much difference of opinion, some naturalists maintaining that they were forms of animal life, and others that they were vegetable. Of course, it is very easy to distinguish an animal from a plant in the higher and more specialised forms, but it becomes a very difficult question, indeed, when those lowly forms are considered in which plants and animals have so much in common that they can scarcely be distinguished by any undoubted characteristics. It is now generally admitted, however, that bacteria and such-like organisms are plants belonging in a general way to the same order of vegetable life as fungi, ferments, &c. —in fact, no very sharp distinction can be drawn between them; they graduate one into the other. The name bacteria is generally restricted to those forms which are the smallest that can be observed and studied under our most powerful microscopes. At one time, indeed, the term was applied only to a certain species, but it has come into use, popularly at any rate, to describe the whole class. Bacteria are exceedingly small. Their size is perhaps about the twelve-thousandth part of an inch in diameter, but they make up in numbers what they lack in bulk, as they exist in untold myriads everywhere around us — in the air we breathe, in the water we drink, in the soil, and even in our own bodies. Every one knows that the air is full of little particles of dust floating about—a sunbeam passing through a darkened room reveals them at once. Now, many of these little particles are bacteria, or their spores, which can be very readily cultivated and grown. If we leave a glass of ordinary water exposed to the atmosphere in a moderately warm room for a short time, it gets covered on the surface with what seems to be dust, but on examining this with the microscope it is found to contain masses of moving and active living creatures. These are bacteria. The number of these germs contained in the air varies considerably according to the season or the state of the atmosphere. As the result of some researches carried on in France, it is found that on the average there are about sixty in each cubic yard of air. Heavy rains, as a rule, reduce this number, but dry weather, on the contrary, raises it. The greatest numbers are found in autumn, and the least in winter. In the neighbourhood of towns and inhabited places generally they are very abundant, while on the tops of high mountains there are few or none. In water bacteria are very much more plentiful than in air. Thus in condensed water vapour there were found in about a quart of the liquid nine hundred, in rain-water sixty-four thousand; while in sewer water, where the food on which they lived is, of course, in great abundance, there were no fewer than eighty millions—nearly three times the population of the British Isles. It is evident from these facts that we are surrounded by these organisms, and must take them by thousands into our bodies; but, at the same time, it is also evident that by far the greater number must be quite harmless, otherwise we could not continue to exist. We cannot destroy them if we would, and if we could the result would be disastrous, for sewerage and other waste products would not be removed from our way. All we can do is to study their nature, habits, and modes of living, and take such precautions as our knowledge suggests to avoid those forms which prove themselves really hurtful to our welfare.

The structure of bacteria, so far as can be observed under our most powerful microscopes, is exceedingly simple. They appear to be just little drops of that wondrous albuminoid substance known as protoplasm, which seems to be essential in some form to all life as we know it. These little drops of protoplasm are generally clear, but sometimes they have a somewhat grained appearance, and are surrounded by a sort of membranous covering of cellulose similar to what enters into the structure of ordinary plants. They then form little cells of a somewhat rounded form, but more frequently elongated into a sort of cylindrical shape. These little tiny cells are, as we have stated, extremely small, but they grow rapidly; and when they attain a certain size they divide into two separate cells, and each of these continue to grow and again divide, so that they increase in a very rapid manner. Although these cells thus divide, they do not always separate, but remain attached to one another, so that as many as ten may exist together as a sort of rod, whence they derive their name of bacteria. Like other forms of animal and plant life, these organisms require oxygen gas for their existence, and many of them take this directly from the atmosphere, but others abstract it from the substances on which they feed. As seen in water, bacteria are endowed with the power of movement; in fact, they never seem to be at rest, and in this they have a great resemblance to animals, but their motions differ somewhat from those of undoubted animals in a want of spontaneity. They move more like automatic or ingeniously constructed machines wound up to move for ever. The cause of these movements is not very well understood; the organisms being so very small, it is difficult to make out any organs of locomotion. Besides multiplying by means of growing and dividing, bacteria also propagate their species by means of true seeds or spores. These appear as little specks or spots in the centre of the cell, and gradually grow, and finally burst through the worn-out cell, and commence afresh the round of life. In certain circumstances when the bacteria are left to dry out of reach of water, these spores are carried by wind and currents of air to some distance, and thus the species is spread from place to place till they find a suitable soil for their growth. These spores are much more tenacious of life than bacteria themselves, resisting the effects of a high temperature much better, and continuing to live in a dormant state for many years. They have been found in the chalk formation, where they must have been buried for ages, and yet on being placed in suitable media have developed into living bacteria. They have also been found in coal, which is much older, but in this case life seems to have become quite extinct, as it was found quite impossible to develop the living organism from them. Their presence, however, in such a situation has suggested the idea to many that possibly the formation of coal may have been largely due to the activity of these lowly bacteria.

We have hitherto considered the useful work which it is the province of these minute organisms to perform, but there is another aspect in which they may be regarded, which is not by any means so pleasant. Many destructive diseases have been traced to bacteria as their cause, and a knowledge of their work in this direction is of vital importance; but we reserve this subject for a separate chapter. These diseases, however, are not unavoidable. Cleanliness, temperance, plenty of sunshine and fresh air may render us impervious to the attacks of these insidious foes.

DISEASE GERMS.

The fact that we are surrounded by myriads of small organisms whose vital action produces fermentation and putrefaction naturally suggests the inquiry as to their action on mankind and the lower animals. As these organisms destroy the bodies of animals as soon as life is extinct, may they not also injure even the living animal, and produce many of those diseases whose origin has hitherto been obscure? The importance of this injury is at once realised when we consider that we must take into our systems, whether we like it or not, thousands of these tiny forms every day. It has been calculated that every one of us must inhale about one hundred millions every year, and as a matter of fact we find them in great numbers in our mouths, stomachs, and intestines. It is worthy of note, however, that they are never found in the blood of a healthy person. By some means or other they are prevented from entering into the general circulation. To the great Frenchman, Louis Pasteur, belongs the credit of having settled this question, and of having proved beyond a doubt that these organisms are certainly the cause of many diseases, and that among the many species of bacteria, &c., there are some forms which produce each its own special disease on man and the lower animals. The history of this great discovery is very interesting and instructive. About five-and-thirty years ago, certain minute rod-like organisms were noticed in the blood of an animal which had died from anthrax or splenic fever, a disease which attacks both man and the lower animals; but no one seems to have suspected that these organisms were the cause of the disease until Pasteur published his remarkable researches on fermentation and putrefaction. It then occurred to Devaine, who had first noticed those little bodies, that they might possibly be the source of the malady. He accordingly took some of the tainted blood and inoculated healthy animals, and found that a very small quantity indeed of the blood produced a fatal attack of the disease. This, however, did not prove that the disease was really due to these germs, because the blood itself might be altered in some way so as to act as a poison. To settle this question, Pasteur took the matter up, and very speedily showed that it was from the germs, and from them alone, that the disease proceeded. The method he employed to prove this was as follows:—He took a drop of the infected blood and added it to a solution prepared for the purpose, in which the germs were cultivated. He then took a drop from this solution and added it to a second solution similar to the first, and again cultivated, and so on for a great many times, so that any poison contained in the blood was diluted to such an extent that it could not possibly have any effect, and he got, in fact, in the last solution nothing but the germs themselves. With these he inoculated healthy animals, and the disease was produced at once, just as with the original blood. The demonstration was complete; splenic fever at any rate was certainly due to the living action of these small organisms, and the existence of disease germs proved. Proceeding in the same manner, Pasteur and many other investigators discovered the specific germs which give rise to a great number of well-known epidemic and contagious diseases. Among these may be mentioned rabies, glanders, fowl cholera in the lower animals, and fevers of various kinds, such as scarlet and typhoid, smallpox, measles, hooping-cough, phthisis, cholera, &c., in man; even the decay of teeth has been found to be due to a particular form which attacks the tooth when the enamel is broken by the action of acids in the mouth. These discoveries have revolutionised our ideas of disease, as these germs seem to be found at every turn doing their hurtful work. Of course, in such investigations where the objects to be observed are so exceedingly minute, it is sometimes not easy to identify the particular germ of any disease, and there may be doubt in some cases, such as cholera, if this has really been done. Although the existence of certain specific noxious organisms which we have called disease germs has been thus satisfactorily made out, the manner in which they accomplish their deadly work is not yet known. It may be that these germs wage war against the cells of which our blood and tissues are formed and destroy them, or they may appropriate to themselves the food and the oxygen intended for the nourishment of our bodies, and thus cause death by gradual exhaustion. Perhaps the best explanation, however, is that which ascribes death to the action of some poison secreted by the organism. We know that those organisms which give rise to putrefaction produce soluble alkaline poisons called ptomaines, and that other forms produce ferments, and it may be that those disease germs also produce a ferment or a poison which acts fatally on the animal system. If this be so, then the action of the germs is indirect, and the really fatal thing is not the germ itself, but the poison which it produces in the system.

However this may be, the fact remains that we are in the midst of hosts of noxious things against which we must wage continued war, and it is of the greatest importance that we should study the forms, habits of life, &c., of these small, almost invisible, foes which work such deadly havoc in our midst, in order to discover, if possible, some defence against their insidious attacks. We may consider those eminent men who, patiently and in silence, microscope in hand, study the varied forms of these germs as in reality an army doing battle with the foe, and in the quiet researches of the laboratory there is often as much heroism exhibited as in mounting the deadly breach. The experiments are not without danger. It is said of Pasteur that he sucked into a tube some of the saliva from the foaming jaws of a raging mad bull-dog held down by ropes: the slightest mistake or slip of the ropes and he might have been inoculated with the deadly virus of this most awful disease. Valuable knowledge has already been acquired by the labours of these investigators, although much still remains obscure. We know where these hurtful forms are most likely to be found in greatest numbers, we know certain precautions which must be taken to avoid them, we know how to kill them, and in some cases at any rate how to mitigate or entirely prevent many of the virulent diseases they bring in their train. These disease germs only live in a thriving condition within certain limits of temperature. At high temperatures they are destroyed completely, and at the boiling-point of water the organisms themselves are killed if the exposure is sufficiently long—sometimes a very short time suffices; but the spores or germs properly so called offer a greater resistance, and the temperature requires to be raised somewhat above this point in order to make their destruction certain, so that they may not spring into active life again when transferred to a suitable medium. At low temperatures, such as the freezing-point of water, these organisms are only paralysed, not killed, so that they renew their activity on the temperature being raised; but so long as the cold is maintained they remain dormant and harmless. It is owing to this action that butcher-meat can be preserved by being frozen, the putrefactive bacteria being rendered harmless so long as the temperature is kept low. It is curious to note that Lord Bacon, among his other little accomplishments of writing tragedies and cryptograms, seems to have had some sort of foreknowledge of this fact; in truth, he met his death in trying an experiment on the subject. Macaulay writes of him that he had an idea that snow might prevent animal substances from putrefying, and one very cold day in the year 1626 he alighted from his coach to try the experiment. He went into a cottage, bought a fowl, and with his own hands stuffed it with snow. In doing this he incurred a chill, which resulted in his death. In the last letter he wrote he mentioned that the experiment had succeeded "excellently well."

Many chemical substances act energetically on the disease germs, and either destroy them altogether or render them comparatively harmless. Among these may be mentioned mercuric chloride, sulphurous acid, carbolic acid, boracic acid, &c. Lister has applied some of these with great success in the dressing of wounds and sores, and in surgical operations. The full action, however, of these substances cannot be utilised when the germs are actually in the body, because the quantity required is often in excess of that which it would be safe to administer. The most promising field for preventing the evil effects of disease germs seems to be that of inoculation. It is well known that some diseases, such as measles or scarlet fever, rarely attack the same individual more than once; the first attack seems to bestow an immunity from that particular disease. Small-pox also is prevented by vaccination, the vaccine matter creating a similar disease of a milder form, which renders the individual proof against the more deadly malady. It occurred to Pasteur that he might find the means of producing the germ-formed diseases in a mild form which would act as a protection in the same manner. This he accomplished in the following way. He made repeated cultivations of the disease germ according to the method already referred to, but instead of making the cultivations rapidly one after the other, he allowed several months to elapse between each, and found that when he did this the germs from the last cultivation were so weakened they could produce the specific disease in only a very mild form on any animal which he inoculated with them. But, as he had expected, this weakened form of the disease bestowed on the animal a protection against the attacks of the germ in its most active state. Pasteur ascribed the weakening of the disease germ by his method of cultivation to be due to an excess of oxygen acting for a long time; for he found, if he took means to exclude an excess of air during cultivation, the germs retained their virulence. Other investigators ascribed the result to the action of heat; but it is quite possible that it may be brought about in different ways; for the organism may be weakened by more than one agency. At any rate, inoculation with these weakened germs was completely successful in the case of splenic fever, as was demonstrated by trial on a large number of animals. The same course of treatment has been adopted in the case of rabies or canine madness, and although some remarkable results have been attained, it cannot be said to have been so undeniably successful; but a great field for investigation has been opened which will undoubtedly yield much good fruit in the future.

The reason why some diseases in a mild form give protection from the attack of the same diseases in a more virulent form is not understood. Pasteur's idea is, that the mild form abstracts from the blood and tissues certain elements which are necessary for the sustenance of the germ, and thus, to use an agricultural expression, exhausts the soil, so that the same germ, even in a powerful condition, cannot thrive on it. This does not seem very satisfactory, as it is difficult to understand how the immunity should continue for years, as we should imagine that the blood and tissue cells would sooner or later recover the elements of which they had been deprived. It seems much more likely that the result is due to the resistance which the living cells of animal bodies offer to the disease germs being strengthened by use. The white blood cells of frogs inoculated with the anthrax germs are observed to incorporate and destroy these germs, and the animal is not affected; but if the animal is kept at a high temperature the germs increase so rapidly that they gain the mastery over the blood cells and destroy them. Now, it is probable that the living cells of the animal body offer more or less resistance to the attacks of these invading disease germs, and if the latter are weak the former may overcome and destroy them, and in so doing may be permanently strengthened to resist all such attacks from the same kind of germ in future, just as all powers are strengthened by use. This acquired strength might descend to cells formed from those who bore the attack. This view might explain why certain individuals seem to enjoy perfect freedom from diseases which strike down many in their immediate neighbourhood, and why, indeed, so many of us continue to exist in the midst of such unknown dangers. The vitality of some may be able completely to resist the attacks of those disease germs, while others, weakened from various causes, may readily succumb. We may, indeed, look upon the whole matter as a struggle for existence between those disease germs and the cells of our blood and tissues. If the former are the stronger they will prevail, and we shall suffer disease, and, it may be, death itself; if the latter are the stronger we shall remain in health. If, however, the germs are excessively numerous, the strongest may succumb to the force of mere numbers. In this view of the case our duty is plain. We should, by every means in our power, keep our bodies in strong vigorous health and avoid everything that tends to lower vital activity, such as exhaustive work, bad or insufficient food or air, excess of all kinds, and by so doing we shall offer a strong resistance to the first inroads of these secret enemies. Again, we should be careful of any disorders in the throat, stomach, or intestines; because, as we mentioned, numbers of germs are always present in these parts even of healthy persons. They may not, indeed, be germs associated with any particular malady, but still they are only prevented by the living action of the mucous membrane from entering into the circulating system, as it has been proved that the action of the gastric juice and other secretions of the body have very little effect upon them. If, therefore, the mucous membrane is injured, they may pass through it and produce many serious disorders. Thus keeping our bodies in thorough and vigorous health, we must avoid all those places where germs are most likely to be found in greatest numbers, such as crowded dwellings, hospitals, &c. We must have plenty of fresh air, and, above all, plenty of sunshine, which is found to be very destructive to those ubiquitous pests. Crowded houses and narrow closes are nurseries for the rearing of these disease germs. Cleanliness is absolutely necessary to check their spread. Linen and blankets soiled by contact with persons suffering from any of these diseases are very dangerous. It is comparatively easy to avoid infection from water, food, or even from drains, if well flushed, but clothes of all kinds dry, and the germs are carried into the air, which we cannot avoid, as we must all continuously breathe it. Of course, when the disease is fairly upon us, there is no resort but to the skilled physician, but by proper attention to health and sanitation his valuable services may be rarely required.

FERMENTATION.

Fermentation, as popularly understood, is that process by which alcoholic beverages—such as wine, beer, whisky, &c. —are produced from grapes, malt, sugar, and other substances. To the chemist, however, who looks rather to the principles involved in the operation than to the special product in any one case, fermentation has a very much wider significance, and includes such processes as digestion and putrefaction, and generally the breaking up or changing of complex substances by the action, direct or indirect, of living organisms of various kinds which have received the general name of ferments. From this point of view there is no subject of greater interest, and at the same time more difficult of investigation—dealing, as it does, with highly complex organic substances, the correct analyses of which require no little skill on the part of the chemist, and with forms of life which the microscope alone can reveal. As the alcoholic fermentation has been more thoroughly investigated than any other form, we shall best understand the principles involved by considering it, in the first instance. Many and varied have been the explanations given in early times of the phenomena of fermentation, but it was not until about the end of last century that a solid foundation for the study of this subject was laid by the distinguished French chemist, Lavoisier. By experiment and analysis of the various products he showed that the sugar from which alone alcohol is produced in fermentation is simply split up into two parts, one of which is alcohol and the other carbonic acid gas, which latter in escaping from the fermented liquid causes the effervescence or boiling from which the process takes its name. Lavoisier's method, as might be expected from the resources at his command, was defective, and his analysis, as afterwards shown, faulty; but he had taken a great step in making a quantitative comparison between the products of fermentation and the source whence these products were derived. A beginning having thus been made, many eminent men took up the investigation, and by improved methods showed that it is not strictly correct to say that the sugar is entirely split up into alcohol and carbonic acid, but that small quantities of glycerine, succinic acid, &c., are formed, and also that about one per cent. of the sugar is united to the fermenting organism. It is clear, however, that in the main alcohol is formed by the splitting up of the sugar by the ferment. This may be called the purely chemical view of the question. All the elements contained in the sugar can be accounted for, and what is called a chemical equation may be arranged to show that, exactly as the sugar disappears, the alcohol and carbonic acid gas appear—always, of course, allowing for the small quantities which have otherwise changed as we have stated. We have now to consider the cause which brings about this breaking up of the sugar. The special agent used in alcoholic fermentation is yeast, a substance obtained from the wort of beer. Among scientific men great difference of opinion long prevailed both as to the exact nature of this substance and as to its mode of effecting the change. Some maintained that yeast was an organism of a vegetable nature, which reproduced itself by means of budding, and they supposed that in some way this organism in growing, or as a result of its vital action, produced the fermentation. Others, again, denied its organic nature altogether, and maintained that its action was what is called catalytic, which is the action which one substance, by its mere presence, sometimes has on the chemical behaviour of another. This, however, explains nothing, as it is itself in need of explanation. The great chemist Liebig took a very decided position in the controversy, and by his ability and influence caused his opinions to prevail to a large extent. He thought that fermentation was caused by the putrefaction of the yeast, and said—"Yeast and in general all animal and vegetable matter in a state of putrefaction will communicate to other bodies the condition of decomposition in which they are themselves placed; the motion which is given to their own elements by the disturbance of equilibrium is also communicated to the elements of the bodies in contact with them."

Practically the controversy was between those who maintained that yeast was a living organism, and that the fermentation was due to its vital energy or mechanism acting on the sugar, and those who, following Liebig, admitted the organic nature of yeast, but ascribed the fermentation, not to its life, but to its decomposition and putrefaction. Among the supporters of the former opinion Pasteur occupies the most distinguished place, as he has, in a series of the most brilliant researches, proved almost to a demonstration the truth of his opinions ; and although it cannot be said that we understand the whole process in every detail, yet his experiments throw a flood of light over what was hitherto most obscure. In fact, there is no doubt whatever that living organic cells, whether separate or forming parts of a complex organism, have a power of originating chemical changes in various substances, and that the alcoholic fermentation is only a particular instance of very important and widespread phenomena lying at the very basis of life.

Although yeast may be said to be *the* alcoholic ferment, it is not the only one, as other organisms have been proved to induce this fermentation to a small extent, so that there is no abrupt dividing line between one organism and another, but only each has a function more particularly its own. Pasteur and others have shown that yeast is an organism of a vegetable nature composed of an outer covering of a sort of cellulose, enclosing albuminous or nitrogenous matter—that is, matter somewhat of the nature of the white of egg—of which nitrogen forms an essential part, and salts of various kinds. Like other bodies of its class, it propagates itself by buds which are thrown off from the parent cell, and it is while the budding or reproductive process is going on that the fermentation becomes active. It grows at the expense of the albumen, salts, and sugar of the fermented liquid, and requires a supply of oxygen to support its vital activity; and when it cannot get this gas in a free state it abstracts it from the sugar, and it is Pasteur's opinion that this is the special cause of the splitting up of the sugar into alcohol and carbonic acid gas. In abstracting the oxygen from the sugar it upsets the chemical equilibrium of that substance, and hence the breaking up. Whether this be so or not, it is perfectly certain that the production of alcohol goes on simultaneously with the growth of the organism, and the latter seems to be necessary for the former, for where there is no growth there is no fermentation. From these results we get a very definite idea of fermentation as the result of the vital activity of a low form of vegetable life planted in a suitable soil, breathing, growing, and reproducing itself at the expense of the medium in which it is placed, and when its energy is exhausted dying, as all things do, and leaving behind it the fruits of its activity. Of the particular process or mechanism by which it produces the alcohol we are yet in ignorance, but no doubt in the course of time this secret also will be yielded to persistent investigation. Extending his observations to such processes as the production of lactic acid from the sugar of milk, of vinegar from alcohol, or of ammonia from wine, Pasteur showed that all these were true fermentations resulting from the action of living organisms, and he was able to separate the various ferments and point out their distinguishing features. In all cases the general principles were the same; the change was brought about by the vital action of the ferment upon the component elements of the fermented substance.

Putrefaction also, which Liebig had assigned as the cause of fermentation, he proved to be itself a process of fermentation; that it was not the spontaneous breaking up of dead matter into simpler forms, but decomposition caused by the active energy of living organisms. The apparent spontaneous development of these various phenomena he showed to be due to the fact that the germs of these low forms of life are everywhere present in more or less profusion, ready to develop into active agents as soon as they find a congenial soil whence they can draw their nourishment. Hence it is necessary, before either fermentation or putrefaction appears, that certain substances, such as albumen, &c., shall form part of the altered body. If certain precautions are taken to destroy all organisms and germs, and to prevent contact with unpurified air, fermentive and putrefactive bodies may be preserved for an indefinite time without change. Temperature also plays an important part in these phenomena; both a high and a low temperature are unfavourable to the life or activity of these low forms of life, as they are indeed to all forms. Advantage of these principles has been taken in the preservation of food of various kinds. Thus butcher-meat is brought safely from distant countries without any other precaution than the subjection to a very low temperature, so as to freeze the juices. Tinned meat, again, is preserved by being first boiled, so as to destroy all organisms, and then carefully sealed out of contact with air, so that no germs may be brought to it. From the action of minute organisms in the phenomenon of putrefaction, it is an obvious step to consider what part these bodies may have in the development of disease, and, as is well known, almost a new science has been created in this direction. But we have already considered this subject in the chapter on "Disease Germs," and only refer to it now to point out the connection with fermentation in the underlying principle of the chemical changes in living matter as a widespread natural phenomenon.

We must now shortly consider another class of fermentive agents which are not themselves organisms, at least so far as can be observed, but are the direct products of organisms. These are termed soluble ferments, and their action indirect fermentation. Ordinary cane-sugar, starch, and analogous bodies cannot be directly changed into alcohol and carbonic acid gas; they must first be somewhat altered into a particular modification of sugar named glucose, which then splits up into the products mentioned. Now, it has been found that water in which yeast has been washed contains a soluble ferment of this class. In fact, the yeast-plant secretes a substance which acts upon cane-sugar, starch, &c., in such a manner as to digest or prepare it for the nourishment of the cell. Analogous soluble ferments are derived from other ferments. This is precisely the same action as takes place in plants and animals in the processes of digestion of the food and nutrition. They cannot directly assimilate the starch and albuminous foods into their composition. These substances must first undergo a fermentive change before they can circulate in the system. Accordingly, we find the various organs of the body secrete soluble ferments of various kinds, according to the nature of the food on which they are to operate. Thus we find in the saliva a fermenting principle identical with the diasture of barley, which acts upon the starch of the food. The pancreatic juice also contains an analogous principle, which acts very energetically on starch. In the liver there is a kind of animal starch which is turned into sugar by contact with blood and a ferment, so that it may enter into the general circulation. Albuminoid and fatty matter are also acted upon in the same or analogous ways by the various secretions, and changed into forms suitable for the nourishment of the system. We thus see that digestion is truly a process of fermentation, produced by soluble ferments secreted by the living cells of the whole structure. The same process goes on in the nutrition of plants. To quote the words of

Pasteur: "Saccharose (cane-sugar), which exists in reserve in the tissues of a great number of plants, is unfit to participate in the nutritive circulation of the plant. It is for this reason that sugar can accumulate and be laid up in store, as occurs in the root of the beet and in the stem of the sugar-cane. The sugar forms a reserve there, while it waits for the moment to begin to act. This period arrives for beetroot when it is about to put forth buds, flowers, and fruit; then the sugar diminishes by degrees and disappears soon after from the tissues and the stalk of the beet, changing into glucose. The leaves at this time contain glucose only; the root yields up its store, and the reserves of sugar which it contained are distributed through the stalk to serve for the purposes of the flower and seed. But this is not possible except by means of a previous transformation, which changes the chemical nature and the composition of the saccharose, and causes it to pass into the state of glucose. This is a true digestion. Beet, therefore, like yeast, and like animals, must digest its sugar."

Some of the changes we have referred to can be brought about by purely chemical means, but there can be no reasonable doubt that the phenomena of fermentation as a whole are associated in a very intimate manner with the nutrition, growth, and reproduction of vital organisms. As the higher forms of life, such as plants and animals, are built up of these elementary cells of different kinds, each discharging its own particular function, it is evident that these same phenomena will play a most important part in their life-history, and that the complete study of ferments and fermentations would include the consideration of the fundamental principles of life itself.

III.

COLOUR.

COLOUR OF FLOWERS.

THERE is nothing in nature which appeals more powerfully to our sense of beauty than the colours of flowers. As we wander through the fields in our summer rambles we are filled with a pure delight in contemplating the varied hues which everywhere surround us; the red and the golden, the blue and the purple, seem to blend, and, as the poet has said, "lose themselves in each other in every bud that blows." So remarkable is the effect upon us that, in the opinion of many, flowers have been specially created for no other purpose than to be things of beauty and a joy for ever to the children of men. Those who thus judge, however, are regarding nature too much from their own stand point, and forget that there are other interests than man's to be considered. This may be, and probably is, one of the purposes for which flowers in all their loveliness were created, but it is not the primary one. Nature, with that wise economy of energy which is characteristic of all her efforts, rarely, if ever, creates beauty for its own sake alone, but combines it with purposes of utility which are as beautiful to the mental vision as the display of colour is to the physical eye, and of this combination the colour of flowers is a striking example.

As every one knows, flowers are essentially the organs of reproduction whose function it is to perpetuate the species. Within their coloured petals or leaves there are a series of slender thread-like organs, the stamens, which have at the top a sort of sack containing a yellow or brown powder named pollen. Inside the cluster of stamens are the pistils, having at their base the seed-vessels, with the ovules or rudimentary seeds. Now, before the seeds can grow they must be what is called fertilised; that is, some of the pollen from the stamens must penetrate into the pistils and reach the ovules, with which they combine. In those flowers in which both stamens and pistils grow side by side this seems simple enough; the pollen require just to be shaken from the one on to the other. This process of self-fertilisation, as it is called, is found to occur in many cases, but if too long continued under the same conditions, it seems to be injurious to the welfare of the plant, just as too close interbreeding is found to be injurious to animals. New blood or new conditions in some way seem to be beneficial in both kingdoms. In plants, therefore, cross-fertilisation is found to be of great benefit. Cross-fertilisation just means taking the pollen from the stamens of one flower and applying it to the pistils of another, and *vice versâ*. Darwin, to whom we are indebted for a great amount of information on the subject, made many experiments proving the great benefits arising from crossing. He planted self-fertilised and cross-fertilised seeds side by side in the same pot under exactly similar conditions, and at once the crossed seeds showed their superiority, the plants they produced being very much larger and stronger, and also containing more and finer seeds, than those raised from self-fertilised seed. So great were the effects of crossing that he came to the conclusion that "nature abhors perpetual self-fertilisation." If this be so, we may expect to find many arrangements among plants for preventing self-fertilisation and inducing cross-fertilisation, and in this we are not disappointed. Thus, sometimes the two organs—the stamens and pistils—on the same plant reach their maturity at different times; so that, owing to slightly different conditions, the stamens of one plant are ripe at the same time as the pistils on another, and the pollen passes from the one to the other, and we have crossing. Again, there are cases when the pistils, from their position, cannot be reached by the pollen from their accompanying stamens. This is so when the former organs grow much higher or the latter bend downwards and away from the former at the season of maturity. In some instances the male and female flowers are on different plants, and this arrangement, of course, absolutely prevents self-fertilisation. We wish, however, more particularly to direct attention to the part which insects play in carrying out nature's plan of promoting cross-fertilising among flowers. In this they act involuntarily, but at the same time accomplish the purpose in a most remarkable and satisfactory manner. They simply carry on their bodies the pollen from one flower to another, and as we watch them buzzing about, landing first on one flower and then flying off to another, we must remember that, while they are feeding and enjoying themselves in what seems rather an aimless manner, they are really carrying out one of nature's great plans for the benefit of the plants on which they regale themselves. The plants, however, have not been slow to avail themselves of these hasty visits, but have developed by natural selection, acting through long ages, various beautiful methods by which the end aimed at is more certainly attained. They have secreted at the base of their flowers supplies of sweet nectar or honey to tempt the insects to push themselves inwards until their probosces can reach the tempting food, and while they are in this position the stamens, by various contrivances, dust their bodies, &c., with the fertilising pollen, which they carry to the next flower they visit. Some of these contrivances are exceedingly curious and sometimes complicated, such as those in which the stamens are brought down by mechanical processes upon the insect on entering the flower, and the pollen scattered on its head or body in such a manner as to be carried to the pistils of the next flower, or the various traps for catching the legs of flies, butterflies, &c., or closed boxes in which the insects are kept till they have fertilised the flower, and many other mechanical arrangements. In some plants there is a sticky secretion which gets on the proboscis of the insect, causing the pollen to adhere to it. In the common cowslip and some other plants there are two or three different forms of flowers; in one the pistil is long and the stamens short; in another the reverse obtains, for the stamens are long and the pistil short. The meaning of this arrangement was not known until Darwin observed that cowslips are absolutely barren, and do not reproduce themselves unless they are visited by insects, and that each form is almost sterile when fertilised by its own pollen or even by that of a similarly formed flower; but, on the other hand, perfect fertility results if the pollen from a flower having long pistils and short stamens be carried to one having short pistils and long stamens, and *vice versâ.* Now, the whole arrangements are such that the insects visiting these flowers bring about this fertile intercrossing between the different forms. Not only, however, do plants adapt themselves to the habits and wants of insects to secure cross-fertilisation, but in some instances avail themselves even of the services of small birds, such as the humming-bird, for the same purpose. In these flower-pitchers and other receptacles containing nectar are formed in such a manner that birds are attracted to them, and while satisfying their appetites are dusted over with the fertilising pollen, to be carried to neighbouring flowers. It may seem strange to include in those arrangements necessary for cross-fertilisation the colour of flowers, which we are so prone to imagine was only intended for the special delectation of man, and yet it is so. There is no doubt that the visits of insects are determined to a large extent by the colour, size, &c., of the flowers. It has been determined by careful observation that the more conspicuous a flower is the more is it visited by insects. It is not supposed that insects possess that sense of beauty which distinguishes the human race, but nevertheless they are attracted by bright displays, and may even recognise differences of tint. Thus, a dozen or more species of insects have been observed to visit the more showy and handsome flowers, while those whose floral decorations were of a more sober type were visited by only about half that number, or even less. Again, white flowers, which are most easily seen at night, are often fertilised by moths; while bright red are the favourites with butterflies, and dull yellow or brown mostly attract flies, and so on, showing that insects have a discriminating power of some kind. There are several advantages, both to the plants and to the insects, which arise from this recognition of differences of colour. In the first place, there is a great saving of time, as the insects pick out at once those flowers which they wish to visit, and pass over the others, and hence can go over a great number in a short time, feeding themselves and fertilising the flowers much more rapidly than they could do without this guide. Many flowers also change their colours after being fertilised, and this is recognised by the insects, who pass over those who by this change show that they have already been visited and their nectar abstracted. Other flowers, again, have certain marks on the petals which guide the insects directly to the opening which leads to the nectar. It is evident from these and many equally remarkable facts that the colours of flowers exercise a powerful influence on their well-being, so far, at any rate, as cross-fertilisation is concerned, and as this is so, the colours must be the result of natural selection. Suppose that all flowers were at first small, and possessed of little or no colour, then the insects would choose for their visits those varieties which were perhaps a little larger and more conspicuous than their fellows. The result of this would be cross-fertilisation and strengthening of those varieties, which would thus have an advantage in the struggle for existence. This would go on and on, every succeeding generation of flowers becoming a little larger and more coloured than the preceding one, until the perfect flower in all its beauty was produced. If the insects for any reason were to cease their visits, then the beauty of the flower, being of no further use, would gradually fade away, although the plants might still live and be fertilised by the wind or other agency scattering their seeds. There is strong evidence that such a process as we have described has actually arisen again and again in the history of plant life. Bright and attractively coloured flowers have been slowly developed by the agency of insects, and when that has been withdrawn the flowers have faded and degenerated into such inconspicuous forms as are seen on grasses and other plants which are fertilised by the wind alone. It is curious to think that all the beauty of form and colour which charms us so much in the flowers of the field is due to the work of insects, and that if there were no insects it would speedily disappear. In short, without insects there would be no brightly coloured flowers at all. We must also be impressed with the fact that the utilitarian processes of feeding the insect and fertilising the plant bring about such a glorious display of loveliness fitted to please and to elevate the mind of man.

COLOUR OF ANIMALS.

THE development of colour in animals is doubtless due to a variety of causes, and hence the subject is a somewhat complex one. The researches of Darwin, Wallace, and other naturalists have shown, however, that colour is no mere accident or freak of nature, without any definite end or aim, but is, like every other characteristic, governed by the great law of utility which dominates the whole organic kingdom, and is subservient to the wants and well-being of animated beings, and is developed by natural selection, which picks out what is most fitted to survive in the great struggle for existence.

If we compare wild with domestic animals, we shall find that there is far less variation in colour among the former than among the latter. In the wild state, the colour of each species is on the whole constant, while among domestic animals the variations in this respect are exceedingly numerous, as we see in horses, dogs, cattle, pigeons, poultry, &c. The explanation of this difference is simple enough. Wild animals are entirely under the control of natural selection, which prevents any great departure from a uniform standard of utility. If, therefore, any variety should appear whose colour is useless or hurtful to the species, then this variety is speedily eliminated. Domestic animals, on the other hand, are protected by man from the action of natural selection; hence colours which might be hurtful in the wild state are preserved, and in many cases developed, by artificial selection.

The inquiry may be made, then, what is the particular use of colour in animals, which renders one shade more suitable in certain circumstances than another? It is evident that the power of concealing itself must be very advantageous to every animal. If it be pursued by an enemy seeking to destroy it, its chance of escape is greatly increased if it can hide itself from the eyes of the destroyer. On the other hand, if a beast of prey be in search of food, its chance of success is greater if it can approach its victim unobserved. Concealment, therefore, is of great use both to pursuer and pursued. It may not seem very obvious that colour can aid any animal in this matter of concealment, as we usually fancy that colour makes an object more conspicuous; but this all depends on the surroundings. A bright object on a dark ground or a dark object on a bright ground are very conspicuous; but reverse the positions, and put the bright object on the bright ground and the dark object on the dark ground, and recognition at once becomes difficult. Now, this principle obtains in the colour of animals, which is found to be adapted to the surroundings. Thus, in the Arctic regions, where snow is on the ground during the whole year, the prevailing colour among animals is white, as in the polar bear, hare, and others. In regions where the snow disappears in summer, some animals change the colour of their coats according to the season, and are white only in winter, such as the Arctic fox and the ptarmigan. We see at once that the colour of these animals must be of great utility in concealing them, as they can with difficulty be distinguished at any distance from the snow around them. In these regions there are some animals which do not conform to the prevailing colour, but are brown or black, like the sable or the raven; but in these cases there is always some apparent reason for this. Thus, the sable in winter-time gets its food from trees, among the branches of which it catches birds. It is, therefore, more advantageous for it to retain its dark coat which assimilates to the colour of the tree, and so to steal upon its victim unperceived, which it could not do if it were white. Turning to the warmer regions of the earth, we find the same principle prevails. In deserts, where the sand and rocks are of a dull earthy colour, the animals partake of the same hue; the lion, the camel, and antelopes are of a tawny or sandy colour. The birds, also, which inhabit these places are all protected in the same way, their plumage being tinted so as to assimilate to their sombre surroundings. In tropical evergreen forests whole groups of birds are green in colour, and in every direction we find the conformity of the colour of animals assimilating to that of the district or region which they inhabit; and no other explanation of this fact is satisfactory, except that the result has been brought about by natural selection in the manner we have indicated. Many adaptations for special conditions are particularly remarkable. In the tiger, leopard, jaguar, and others of the cat tribe, the stripes, spots, and other markings would seem to make these animals conspicuous, and yet in their native haunts the colours so harmonise with the surroundings as to render them almost invisible. The tiger, for instance, frequents districts where the grass is long, dry, and pale yellow; and this, with the shadows which it casts, so harmonises with the dark and light yellow stripes of the animal, that it is only seen when closely approached. One hunter says that in such a situation he failed for at least a minute to see a wounded tiger, although he was within sixty feet of him in an open jungle. Another instance of striking colours affording the means of concealment is found in a species of fruit-pigeon, which has a white head and neck, black wings and back, yellow belly, and deeply-curved black band across the breast. Yet an observer states, regarding this bird, that it was with the utmost difficulty that either he or his sharp-eyed native servant could detect them, even in trees where they knew they were sitting on well-exposed branches. These trees have a yellowish bark and very open foliage, and the intense sunlight coming through casts dark curved shadows, and the appearance tended to assimilate to the markings of the birds, which were thus rendered almost invisible. Even the gigantic giraffe is not readily distinguished among the dead and broken trees near which it feeds, its peculiarly coloured skin as well as its strange form often causing it to be mistaken for one of these.

Among the lower forms of animal life there are some curious combinations of colour and form which imitate some inanimate objects, such as sticks, leaves, &c., so perfectly that a close inspection is necessary before their real nature is discovered. Thus, the leaf-insects of Ceylon and of Java are coloured and veined, with leafy expansions on the legs, &c., so that few people can recognise them, even when close before their eyes, on the food-plant. One writer says regarding the behaviour of the green leaf locust, which closely resembles a green leaf: "This insect stood immovably among a host of ants, many of which ran over its legs without ever discovering there was food within their reach. So fixed was its instinctive knowledge that its safety depended on its immovability, that it allowed me to pick it up and replace it among the ants without making a single effort to escape." This incident shows at once the perfection of the likeness to a leaf and the value of the character to the locust, as these ants devour every insect they can catch. Some caterpillars imitate most minutely the appearance of little twigs, and when at rest stand out from the branch, holding on by their hind pair of claspers. In this position they remain motionless for hours, and deceive the most acute and experienced eyes, as they are invariably mistaken for twigs. The varied and beautiful tints of moths and butterflies can in many cases be also traced to this same cause. In some parts of South Africa the foliage is of a white and silvery character, and many butterflies in these regions have acquired tints of a similar nature. In Calabar and Cameroons, again, the butterflies are light brown, with numerous small white spots, and the soil of these countries is formed of a light brown clay, with small quartz pebbles. These examples might be multiplied almost without end, all showing the same wonderful assimilation of the colour of animals to that of their surroundings, and we cannot doubt that this has been brought about for the protection of the animal by concealment. When insects, for instance, first appeared and fed on vegetation they may have been of one uniform tint, but variation would appear, and those which caused them to look somewhat like the leaves, &c., on which they fed would hide them from their enemies, and thus, giving them an advantage in the struggle for existence, would be preserved and become more and more developed and pronounced as the ages rolled on.

Hitherto we have considered colour developed for the purpose of concealing the animal possessing it, but there are cases where it seems intended to deceive or to attract attention. An instance of the former is given by Mr. H. O. Forbes. On going through a jungle in Java he came upon a bush, on a leaf of which he saw a butterfly apparently sitting on a bird's excreta. On approaching the butterfly it did not move, but allowed him to seize it, when, to his surprise, part of its body adhered apparently to the excreta. On examining this more closely, he found, to his astonishment, that it was in reality a spider most artfully coloured to resemble a bird's droppings, and this, of course, had deceived the butterfly and led to its destruction. Some animals have colours or marks on their bodies which seem rather fitted to attract attention than to afford the means of concealment, and the law of utility seems to fail in these cases. Thus, Darwin considered that the rabbit, when running to its burrow, is made conspicuous to the sportsman, and no doubt to all beasts of prey, by its upturned white tail. This, of course, is hurtful to the species, and natural selection ought to remove the mark, unless it serves some purpose which more than counterbalances the danger referred to. It has been suggested, therefore, that in this particular case, as well as in others of a like nature, the peculiar marking is intended to attract the attention of individuals of the same species, to warn them of danger, or to make them aware of the presence of friends. Such information would undoubtedly be useful to gregarious animals, and tend to their preservation. Thus, suppose a number of rabbits feeding in the twilight, and some of them suddenly become aware of an enemy being near: they at once make with all haste towards their burrow, and as they run their white tails rapidly moving attract the attention of the others, and warn them of the proximity of danger and the need of seeking shelter without delay. Many other examples of the use of colour in animals might be mentioned did space permit, but sufficient have been given to show what an interesting subject it is, and how much the safety and well-being of animal life depend upon colour.

WARNING COLOURS AND MIMICRY.

In the last chapter we noticed the development of colour in animals as a means of concealment from enemies, and also as a guide or warning to friends, and it is interesting to observe how nature, by a slight modification, turns the same characteristic to account in another way, and by making the colour prominent and easily observed, protects the animal in an equally effective manner. There are many animals which would naturally be devoured by others if they did not possess something offensive, unpalatable, or even dangerous to their enemies; and these animals are generally very conspicuous, having markings or colours which are easily recognised at once. There are certain families of butterflies, for instance, which illustrate this fact. These butterflies are very numerous in the great tropical regions, and their mode of flight and peculiar colours single them out so that birds and insect-eaters can have no difficulty in recognising them even in the midst of many others. Now, these butterflies have juices in their bodies which emit a powerful odour which is very offensive to insect-eaters. We can, therefore, understand how their peculiar distinctive colours are useful to them. If they were not so specially marked their enemies might seize them before discovering how distasteful they were as food, and only reject them when they were fatally injured. But being so distinguished, they are passed by without being subjected to this dangerous trial. Certain beetles, also, are distasteful and are not readily eaten, and these are generally made conspicuous by some peculiarity of colour-markings. Caterpillars also afford many instances of bright markings, being used not for the purpose of concealment but of making them conspicuous, and these make no attempt to hide themselves, but rather, as it were, court observation, that they may be seen and recognised as not fit for food. Many experiments have been made with such species. They have been offered to birds, lizards, frogs, and other insect-eaters, who almost invariably rejected them. Even in cases where they seized them they soon discovered their mistake, and spat them out with evident disgust. Since these rejected caterpillars were all brilliant in colour, it is evident that in a state of nature they would be easily recognised and avoided, and thus their very conspicuousness would act in the way of preserving them. Wasps, also, and insects of a like nature, having powerful and dangerous stings, need no concealment, but rather court prominence as creatures to be avoided; and they are generally brightly and conspicuously coloured, and in all cases this must act for the advantage of the insect, and has doubtless been developed by natural selection.

This principle of protection by colour warning off possible enemies is found pretty widely applied among various natural orders, and has given rise to a very remarkable phenomenon, which has been named mimicry. As these brightly coloured and conspicuous insects, &c., are all either dangerous or unsuitable for food, and are consequently generally left unmolested, it is evident that if other animals who possess none of their peculiar properties could imitate their outward appearance, they might easily be mistaken for them, and thus have a chance of escaping from their enemies; just as a countryman who had never handled a rifle or a sword might be mistaken at first glance for a soldier if he donned a red coat and a spiked helmet. Now, such an imitation of outward markings actually does take place in many cases. It had long been known that many moths, for instance, resembled bees, wasps, and suchlike insects, but the significance of the facts was not appreciated for a long time. Mr. Bates was the first who pointed out the explanation of these curious phenomena. He had been studying the butterflies of the Amazon, and among these noticed many species which had warning colours such as we have described, and occasionally he found quite distinct species so coloured that they could not be distinguished from the former without a close examination. Almost in no feature were the species alike, except in outward form and colour. The former species were offensive in odour and taste to insect-eaters, while the latter were not, but had adopted the same outward appearance for the sake of protection. Mr. Wallace, who has closely studied this subject of mimicry, gives many curious and striking examples of it. He mentions that in Borneo a large black wasp whose wings have a broad white patch near the apex is closely imitated by a beetle, which, contrary to the usual habits of beetles, keeps its wings expanded to show the white patch on their apex, the wing-coverts being reduced to small scales. He considers this a remarkable instance of mimicry, because the beetle has had to acquire so many new characters, such as the expanded wing with the white spot, the scale-like elytron, or wing-cases, &c. Tiger-beetles are imitated by crickets and other more harmless insects.

Although it is among insects and the lower forms of animal life that mimicry is most general, yet it is by no means absent in the higher forms. Thus in tropical America there is a genus of poisonous snakes that have a peculiar arrangement of colour, consisting of rings of red and black, or red, black, and yellow alternating. Now, this peculiar arrangement of colour is not found in any other snakes in the world. But in the same regions there are some species of harmless snakes which are so exactly like these poisonous species that it is with difficulty the one can be distinguished from the other. In South Africa there is an egg-eating snake which has neither fangs nor teeth, which, nevertheless, very much resembles an adder, and when alarmed flattens out its head and darts forward with a hiss, as if to strike, just as the adder does. Even among birds there are some cases of this mimicry, although not quite so apparent as in the cases we have mentioned. Birds depend for their safety more on their activity and developed instincts, and hence mimicry is not so useful to them, and, therefore, is not developed to any extent.

The phenomena of mimicry are so remarkable that it is somewhat difficult to imagine that they are due to accidental variation and adaptation to circumstances in order to secure safety to those animals who have no other powerful means of defence. But when we consider all the facts no other explanation seems satisfactory. The imitators are always more defenceless and less numerous than those which they imitate, and, moreover, they always live in the same district; and if the likeness was only accidental, why should it never arise between species occupying widely different districts, and why should it be entirely confined to external appearance and never extend to internal characters? It is impossible to doubt that it has arisen through natural selection, which, as we have already pointed out, is competent to cause insects to assume the likeness of natural objects around them, such as leaves, twigs, flowers, &c., in order that they may be protected by concealment among these objects. It does not seem, therefore, unnatural that the same cause should also produce likenesses to other insects, if by this means safety or benefit of any kind can be secured. The only difference is, that in the one case the benefit is derived from concealment among vegetable forms, from which they cannot readily be distinguished, and in the other from concealment among animal forms like themselves. If we have a number of butterflies which, for some reason, insect-eaters will not touch; and if among these there is one butterfly which exactly resembles them in outward appearance, but which the insect-eaters would eat if they could distinguish it, that butterfly has as much chance of escaping as one hid among leaves which it closely resembled, and which would not be taken as food by insect-eaters. It is not difficult, also, to understand how both the warning colours of hurtful species and their imitations by innocuous species have arisen through natural selection. Suppose that in early times some butterflies, owing to the food which they ate or from some other cause, began to secrete disagreeable juices, the birds which attacked them would begin to dislike them, and would, after tasting, reject them. Of course, by this treatment they would be generally fatally injured; but if among the many variations which occur some were produced with striking colours, the birds would very soon recognise these as disagreeable, and leave them untouched, while they would still destroy those not so marked. There would thus be a selection of coloured individuals as fittest to survive. In the next generation by the same process these colours would become more conspicuous, and so on, until the gorgeous markings they now possess were fully developed. While this process was going on among these disagreeable species, it might easily happen that among those species which were perfectly free from obnoxious qualities some individuals might arise which resembled closely in appearance the former, and would be mistaken for them by the insect-eating birds, who would, therefore, avoid them. This freedom from pursuit would give these individuals an advantage, and hence they would increase. This action would cause in course of time the noxious and the harmless species to assimilate in outward appearance, as we observe they do. Mr. Bates found that, just as the noxious species varied in appearance from district to district, so did their imitators. They followed them exactly, so that they presented "a palpably intentional likeness that is perfectly staggering," and also "that those features of the portrait are most attended to by nature which produce the most effective deception when the insects are seen in nature." From a consideration of these phenomena we see the wonderful flexibility of nature, and how extraordinary and beautiful results are brought about by simple and apparently inadequate means acting through long periods of time.

IV.

MOVEMENT.

MOVEMENTS IN PLANTS.

To ordinary observation plants seem stationary objects, having little or no movement. They grow indeed, but so very slowly that it is only after the lapse of some considerable time we observe any changes in their appearance. On more careful investigation, however, we find that this apparent inactivity is due more to the imperfection of our senses and to the superficial nature of our observations than to the want of motion in plants themselves, and that in truth they are continually moving in a variety of ways; and these movements are of particular interest, as they are closely connected with the well-being and growth of the plants. In many respects they behave like animals, and although their organs are not the same, yet they serve similar purposes and perform analogous functions. Although, for instance, they have no specialised organs of vision, yet they are guided and influenced by the light in all stages of their existence. They communicate sensations, or something analogous, from one part of their structure to another, as if possessed of nerves; and light or other physical agent acting on one part influences the movements of another part, just as the light received by the eye may direct the movements of the hand or any other organ of the body. These various movements have been studied by many eminent botanists, and especially in this country by Charles Darwin, with great care, and many interesting facts have been brought to light. Now, there is little doubt that the phenomena we are considering are due primarily to the extreme sensitiveness of the protoplasm of which all plant-structures are built up. As we pointed out in a former chapter, this substance is suspectible of change in form, &c., when acted upon by the slightest impulse from without, and its growth can be accelerated or retarded by causes which cannot be readily detected. When a little stem or shoot rises above the ground, it does not grow equally all round, so that the whole shall rise straight upwards at once, but as it were bit by bit, one side growing faster at one time than another. We may get some idea of this, although the analogy is not strictly correct, by considering the building of a tall chimney-stalk. If we had a great number of men working all round, and every one putting in a brick at the same time, a complete circle would be added at once, and the stalk would rise simultaneously all round by one course of bricks at a time ; but if we had only one or two workers building up two or three bricks at one part, and then passing to the next part, and adding two or three to it, and so on, we should have an unequal rise of the stalk, first rising at one side, and then passing round the whole structure. Thus the stalk would rise in a sort of spiral manner.

Now, something analogous to this takes place in the growth of plants. If we divided the rounded growing stem into divisions by lines something like parallels of longitude on a globe, we should find the strongest growth taking place first in one parallel, and then passing to the next, and so on until it passed round the whole stem. The effect of this mode of growth is very peculiar. Suppose, in the case of the chimney-stalk, instead of building it by adding course after course of bricks to its top, we forced in bricks at one side between the layers already placed, it is evident that side would rise higher, but it would be forced to lean over somewhat towards the lower side; in fact, the whole stalk would be bent away from the side which was highest. This mode of procedure would more accurately represent the growth of plants. In them, therefore, we find this bending. The side which grows fastest bends over, and the stem becomes curved towards the side which is growing least. Something like this happens if we take two strips of different metals which expand differently under the influence of heat, and, fastening their ends securely together, expose them to a high temperature; the one which expands most gets longer than the other; but as it is firmly fixed, the result is, the combined strip bends over, the metal which expands most being on the convex side, and that which expands least on the inner or concave side. We have then, in the first place, the bending of the stem or shoot so that its point is directed away from the side in which growth is most vigorous. But it does not remain long in this one particular position, because, as we have stated, the growth passes round from one part of the shoot to another; so that the side which was at one time growing most vigorously becomes, at another, the part where growth is least, and *vice versâ*. In consequence of this the shoot is bent in different directions in succession. For instance, when the growth is greatest on the north side the shoot is bent to the south; as the growth proceeds round, say, to the east, then the shoot bends to the west, and so on towards all points of the compass. The end of the shoot thus describes a circle or figure of some sort, according to circumstances, and the growth is not straight upwards, but in a sort of zig-zag direction. Hence we get from this fundamental fact of inequality of growth a continual kind of swinging motion of the growing parts of the plant, from which many important results follow.

There may, however, be movement without growth. In certain parts of some plants cells are developed in which growth has been arrested; but these cells swell up, expand, and then contract again when stimulated by outside agents, such as light, heat, &c. Now, if there are some of these cells in a leaf-stalk, for instance, and those at one side swell up, they will evidently tilt the stalk over to the opposite side, and when they contract the stalk will regain its original position. Then those cells on the other side may give rise to a similar movement, but in the opposite direction; and thus between the two there may be a swinging backward and forward of the leaf-stalk at regular times, and, of course, the leaf itself will partake of this movement and regularly rise and fall. The whole arrangement is like a spring or cushion causing the leaf or branch to assume different positions.

Keeping in view these movements, caused by inequality of growth, and the extreme sensibility of protoplasm to outside agents, such as gravity, light, heat, contact with other bodies, &c., we are prepared to understand many of the phenomena of plant life. When the little rootlet springs from the seed, its points tend to grow straight downwards into the earth in search of nourishment, and a secure foothold for the entire plant. The slight gyratory movement we have described enables it to search about, as it were, for some opening or easy path through which it may pass downwards as it grows. Should it meet with some hard object, such as a stone, directly obstructing its progress, it turns aside, not by the mere effect of pressure forcing it to grow in another direction, but by its extreme sensitiveness to touch; for it has been shown that the force with which it presses on such an obstacle is almost inappreciable, and yet it may turn aside at a right angle; the touch is sufficient to direct the growth. The sensitive point acts on the growing part of the root and bends it to one side or the other of the opposing body, where it renews its search for a downward path, which it no sooner finds than it turns again to its original direction. According to Darwin, there is nothing more wonderful than this tip of the growing root. Although plants have no nerves or nervous system, yet the tip of the root acts as if it had these organs; for it transmits impressions which it receives. If it be pressed or injured in any way, it causes the upper adjoining part to bend away from the affected side, and, indeed, can distinguish between a greater and a less pressure applied at the same time. It is also capable of detecting moisture in its neighbourhood, and will cause the growth to bend towards it, so that it may avail itself of the nourishment which it affords. In fact, it leads and directs the downward movements of the whole root, as if it were the brain of an animal receiving impressions, and sending them along a nerve. Other rootlets springing from the sides of the first are not so sensitive to what may be called the effects of gravity, and therefore do not tend to grow as straight downwards, but spread out somewhat laterally, directing their courses, however, in a similar manner, so as to get a good grip of the soil and bring in all the nourishment that can be found. The growing root, therefore, burrows like some animal in the ground, searching out for the easiest path, and for those parts where nourishment most abounds, guided by the infallible instincts of its growing cells.

The stem of the plant is not sensitive to what we have called the effects of gravity, and therefore grows upwards, but it is exceedingly sensitive to light, heat, and other agents. When the stem, leaves, &c., are placed in such a position that they receive more light on the one side than on the other, they tend generally to bend towards the side where the light is greatest. So sensitive are they in this respect, that the little leaflets first developed have been observed to be affected by a difference in the degree of light falling on their two sides which could not be distinguished by the eye. The leaves of some plants, when exposed to the full light of the sun, twist round so that their edges only are presented to him; they thus escape from the full force of his rays, which might prove injurious. Other leaves again fold themselves up or droop downwards, and assume various positions at night, all calculated to shield them from the effects of a chill, which might injure their delicate structures. Stems and branches move about searching for supports, on which to rise to the light and aid them in their struggle for existence. All is in continual motion in every growing part, and even in many parts which have ceased growing. The causes of these and many other movements of a like nature are often extremely complicated, and in many cases not very clearly understood, but the general principle seems satisfactorily established, that they are, for the most part, due to unequal growth of the different parts of the plant, modified by the effects of various agents acting from without. We must regard plants, therefore, not as motionless organisms growing steadily in one direction, but as active living creatures, instinct, as it were, with life and motion in every part; every growing twig or leaf pursuing its daily or hourly course, searching diligently all round its little sphere of action for conditions most favourable to its growth and well-being; every little rootlet burrowing through the earth in all directions, seeking for nourishment and support, and every movement tending to give them some advantage in that great struggle for existence which is the inevitable lot of every living thing.

SLEEP OF PLANTS.

Among the many phenomena due, for the most part, to unequal growth and movement, one of the most interesting is the changed position which the leaves and petals of some plants assume during the night. As animals coil themselves up or assume positions of rest during the hours of sleep, so do leaves fold and turn themselves as the shades of evening advance; and although there may not be a strict analogy between the two processes, yet the outward resemblance is so striking that the latter phenomenon has been called the "sleep of plants." Every one must have observed flowers closing their petals at night. In their case, however, the movement is more due to changes of temperature than to those of light, although, no doubt, the position assumed by the petals protects the organs of reproduction, the pistils and stamens from cold winds and chills, and possibly from the inroads of injurious insects. We shall not, therefore, specially consider them, but confine our attention to leaves to whose movements the term sleep has been more generally applied, and which are due more to changes of light than of heat. These movements are extremely varied, and in some cases complicated. We shall, therefore, describe several to show the different positions assumed before considering their uses and cause. The simplest movement is an up-and-down one, the leaves rising or falling at night, so that, while they may be spread out horizontally during the day, they assume at night a more or less vertical direction, their tips pointing either upwards to the zenith or downwards to the ground. We have a remarkable instance of this in a species belonging to the family of Oxalidæ. The leaves or leaflets of this plant are arranged on both sides of a central leaf-stalk, and during the day spread broadly out in lateral directions; but as the sun declines they seem, as it were, to become limp, and one by one droop downwards until they point directly to the ground, hanging closely together back to back, and their surfaces no longer looking upwards, but sideways or towards the horizon. Another plant belonging to the Leguminous family, which includes more sleeping species than any other, has a closely analogous movement, but slightly modified. Their leaflets are arranged much in the same manner, but instead of falling down they move upwards, and bring their upper surfaces close together, thus sheltering them completely and exposing only their backs. In addition to this movement, they bend towards the main stem, so as to be, as it were, almost along the leaf-stalk with their side edge turned upwards to the zenith.

The turning of the upper surfaces of leaves inwards is a very common phenomenon among sleeping plants. Many rise upwards and curve over so as to form a sort of closed cup, the upper surfaces forming the inside. It seems as if there were some special reason why the upper surfaces of leaves should be protected from the night air. In another order of plants, the Lupines, the positions assumed by the sleeping leaves are somewhat different from the foregoing. In these plants the leaves are palm-like, and radiate from the end of the stalk in the form of a sort of star, which in the day-time is presented upwards. In some species when night comes on the leaves of this star rise vertically upwards and form a sort of open cup, while in others they fall downwards over the stalk, and become crowded together as if for mutual protection. In several species, however, quite a different arrangement takes place. The leaves at the one side rise up, while those immediately opposite fall down, and the intermediate ones twist themselves half round on their axes. The result of these movements is, that the leaves still preserve their star-like arrangement, but it is turned round through a right angle, so that the star no longer looks upwards, but to the side, and its edge only is exposed to the sky. The sleep of some kinds of Acacias is also very remarkable. The little separate leaflets of which the leaves are formed fold themselves on the central rib, which then droops downwards from the stalk, and the whole arrangement looks like a stalk with bits of cord or twine dangling from it. In many species of Cassias the movements are somewhat complex, for while the leaf falls downwards, it also twists round so as to make the upper surfaces face one another; and not only so, but the leaf-stalks partake of the movement and close upwards towards the central stem, thus making the whole plant, as it were, contract into smaller space, so that it exposes a much less extent of surface to the night air. In one species the leaves do not rotate so much, but simply fall down, while the stalks rise up almost vertically, thus, as it were, folding up the whole plant something like the closing of an umbrella, where the wires represent the leaf-stalks rising upwards and closing on the central stem, while the silk cover represents the leaves falling down. The result is, that the surface exposed at night is only a very small part of what is exposed by day.

There is an endless variety in these movements of closing up, twisting, and folding of leaves and their stalks, but enough have been described to show their general character and appearance. Now, we know that nature rarely does anything that is not of some use, and we may be sure that the sleep of plants attains some end beneficial to these organisms. As a general rule, leaves in the day-time spread themselves out in a lateral direction, so that their surfaces may be fully exposed to the genial influences of light, heat, and air; but it is evident that such a position may not be the most suitable, at least for all plants, when these give place to the cold and chill, or even the lowered temperature of night. We know that all bodies radiate into space during the night the heat which they have acquired during the day, and the greater the extent of their surfaces which is fully exposed to the heavens, the greater is this radiation and consequent loss of heat; and from this cause the temperature of plants might be so much lowered as to be injurious to their delicate structures. Gardeners and others who cultivate plants are quite aware of this danger, and frequently protect them with some sort of loose covering at night, and nature seems to have the same end in view in developing these sleep movements. If we consider the examples we have given of these phenomena, we shall see they all result in exposing as small a surface as possible to the full effects of radiation; the leaves are turned so as to present only their edges, or at least their surfaces at a considerable angle, towards the sky, while the full surfaces are turned sideways, in which position they are protected from the full effects of radiation by neighbouring objects. In order to test this view of the matter, Darwin made a series of experiments. He fixed the leaves of many sleeping plants so that they could not change their positions at night, and thus their surfaces were fully exposed to the effects of radiation. As might be expected, the temperature of those leaves which he had fastened down was lowered considerably more than that of those leaves which were left free to their natural movements, and they generally suffered severely in consequence. There is little doubt, therefore, that, in the majority of cases at any rate, these sleep movements are the means adopted by nature to protect plants from the injurious effects of a too great reduction of their temperature by radiation of heat and space.

In order that plants may sleep properly, however, it is necessary that certain conditions of heat, light, &c., should be observed. It has been found, for instance, that a plant which did not sleep at all when exposed in the open air, although it seemed quite in good health, slept in the usual manner when transferred to a warm greenhouse. Plenty of light during the day is also quite essential in many cases, and unless this has been obtained sleep will not follow at night, even although the temperature be kept at the proper point. The quantity of moisture in the ground and in the air has a powerful effect, and if the latter be too dry the movements may be entirely stopped. Violent motion, such as agitation by a strong wind, interferes with the regularity of these sleep movements, and is sufficient to prevent their occurrence for some time. From many experiments which have been made, it is certain, however, that the periodicity or regular recurrence of these movements at stated times is due to the alternations of light and darkness; not, however, so much to the greatness of the change from the one to the other as to the fact of the change itself. No doubt leaves assume their usual position in the morning, even when light is excluded, and some move in a regular manner in darkness for some time; but this is probably due to inheritance; for it has been observed that plants in their native homes change their hours of sleep according to the changes of the seasons.

In regard to the cause of these movements, it has to be noted as a significant fact that leaves, when they assume the position of sleep, do not remain perfectly still until the hour of awakening arrives. They continue to move during the whole twenty-four hours; and their movements are much more extensive when going to sleep at night and when arising in the morning than at any other time; but still they move even in sleep unless they come into very close contact, when they are mechanically prevented from doing so. This peculiarity shows that sleep movements primarily arise from those general movements which are common to all plants, and which have been already described. Every leaf and twig moves about in an approximately circular or elliptical and spiral manner, and it is only necessary that this regular movement be modified in a particular direction to produce all the phenomena we have described. Suppose that the leaf is moving regularly, and at a certain hour. Some stimulus, such as a change in the intensity of light, is applied so that the leaf or stalk continues its movements to a greater extent in one particular direction, and then after the lapse of some hours the stimulus is reversed so that the leaf moves to a greater extent than usual in the opposite direction; it is evident that the circle or ellipse which it describes will become more and more lengthened into the oval form; and as the plant's energy is used up to some extent by its extended movement in the two directions, its motion at right angles to these directions will be diminished so that the oval will gradually approximate to a straight line and the leaf move backwards and forwards or up and down, as the case may be, at regular intervals. Now, we know that the presence or absence of light has great influence in retarding or promoting growth and in causing cells to swell up or contract, even where there is no growth; and as both these phenomena are concerned in sleep movements, we can easily understand how change from day to night, or *vice versâ*, can cause leaves or stalks to rise up, fall down, and move in various ways, so as to give rise to those remarkable appearances presented by sleeping plants.

CLIMBING PLANTS.

There are many plants whose stems are not rigid enough to support themselves in an upright, straight position, and which would, therefore, be compelled to trail along the ground, and would not be able to bring their leaves, &c., within reach of the sun's light when they were surrounded by vegetation of a firmer type, if they were not provided with some special means of overcoming this difficulty. Nature has, therefore, developed in them some remarkable powers of climbing, and utilised for this purpose those spontaneous movements which are so general in all plants, and that sensitiveness to stimulus which is especially characteristic of protoplasmic cells. Plants endowed with these special powers climb in an endless variety of ways, which may, however, be all included under three or four methods. First, the twining of the growing stem round some support; second, the modification or development of certain organs, so that they can seize hold of any object and clasp it firmly; and lastly, the development of hooks or rootlets, which can cling on to or embrace the trunks of trees, &c.

Twining seems to be the simplest method, and, probably, was the earliest developed, as it is really just a slight adaptation of that general movement arising from inequality of growth to which we have referred. Darwin says, referring to the hop-plant: "When the shoot rises from the ground, the two or three first-formed joints are straight and remain stationary; but the next formed, whilst very young, may be seen to bend to one side and to travel slowly round towards all points of the compass, moving, like the hands of a watch, with the sun. The movement very soon acquires its full ordinary velocity; the average rate during hot weather and during the day is two hours and eight minutes for each revolution. This movement continues as long as the plant continues to grow; but each separate joint, as it becomes old, ceases to move." The extent of space passed over in this circular motion is often very considerable, the tip of one hop-shoot describing a circle of nineteen inches in diameter; and one of another species of plant, allowed to grow out horizontally, took about six hours to complete its journey, passing round a circumference of no less than sixteen feet in that time, at the rate of about thirty-two inches per hour. This, of course, is an exceptionally large sweep, but it serves to show the nature of these movements. It is evident that such extensive spontaneous movements are admirably adapted for the purpose of searching for supports. Should a stick or other upright object be placed in the path of such a moving shoot, at a distance a little less than its full swing, it will, of course, arrest the movement of the greater part of the shoot; but the tip will still continue its forward progress, and this will cause it to curl round the stick, and as it continues to grow it will curl more and more, ascending the stick, as it does so, in a spiral manner. This action has been very naturally compared to that of swinging a rope horizontally round the head, and should that rope meet with an upright post, it will by its arrested motion twist rapidly round it. Every one has noticed this kind of action, and it very fairly represents the movement of a plant twining round a support, although, of course, the causes are different. The rates at which twining plants perform these movements differ considerably, the time of one revolution varying from about an hour and a half up to as much as twenty-four hours or so, and sometimes the motion is accelerated when the shoot is moving towards the light and retarded when moving from it. When the shoot does not find any support it bends downwards until it rests upon the ground, but with its tip often turned upwards, preparatory to a renewed search all round from its new position. In some cases, when the search for an outside support has proved fruitless, the shoot turns inwards and clasps its own stem; or several shoots intertwine so as to make a sort of twisted rope for mutual aid. The cause of the twining seems to be due entirely to the mechanical arrest of the motion of the shoot by the obstructing support and the continued growth and movement of the tip and part which stretches beyond the support, as there is no evidence that the stems of these plants are sensitive to contact so as to have their growth modified in any way when they meet an opposing body.

From twining plants we pass by a sort of natural gradation to leaf-climbers, or those which climb by means of sensitive leaves or leaf-stalks. There is no sharp line of separation between the two classes, however, for some of the latter retain their power of twining to some extent. Thus, a species of clematis was found to make two or three turns in one direction round a stick placed near it, then to ascend straight up for a short distance, and finally wind again in a direction opposite to the first. The revolving of the shoots, although present in many cases, is not so much utilised for climbing as for aiding the movements of the leaves, &c., in searching about and bringing them into contact with surrounding objects, which they no sooner touch than they firmly seize. In order to do this the leaves and leaf-stalks of these plants are endowed with extreme sensitiveness to touch. While ordinary twining plants will only wind round a support in the direction in which they are moving at the moment of contact, leaf-climbers will twine in any direction, always turning towards the object which touches them, as they are sensitive on all sides, although sometimes in different degrees. The extraordinary sensitiveness to touch of some plants may be understood from the fact that a loop of thread, weighing only the sixteenth part of a grain, placed on the leaf-stalk of one species caused it to move slowly through an angle of ninety degrees. Even the touch of a withered blade of grass is sufficient to cause some of the more susceptible to seize it. Many of the arrangements of the leaf and stalk are most ingenious. Thus sometimes, when growing, they bend down and curve inwards so as to form a sort of hook or loop admirably adapted to grapple any object that may come in their way. When one of these sensitive leaves touches anything, the stalk rapidly twists round it, if it be a suitable support, and after two or three days grows much thicker and stronger, becoming more woody in its structure, and thus firmly fixes the plant. When the touch is only temporary the leaf-stalk bends for some time, but finding no proper support, straightens itself again and resumes its search for something more substantial. The whole movements seem almost as if directed by intelligence. In some species the climbing apparatus is placed on the tip of the leaf, which is lengthened out into a narrow ribbon-like projection, which ultimately becomes hooked and strong enough to hold on and anchor the plant to its support. If nothing is caught for some time the hook gradually rolls itself into a coil, and its sensitiveness is entirely lost. It is rather a curious fact that the leaves on the summit of a full-grown plant of this kind are not sensitive, and cannot seize a stick. The plant, having grown to its full height, cannot be raised any higher, and, therefore, sensitive leaves are of no further use to it, and are consequently not developed.

From plants which climb by means of sensitive leaves and stalks, it is a natural transition to pass to those which develop special organs for the purpose, such as the pea or the vine. These organs are called tendrils, and are formed by changes in leaves, stalks, or stems, by which these are completely altered in character, and form grappling apparatus of great flexibility and strength. The gradual alteration in form is in some cases very marked. Thus in one plant the first-formed leaves are quite normal and complete, but the next have their leaflets reduced in size; the next again are smaller still; and, finally, the leaf seems to disappear altogether, and its place is taken by little threads or spines, which pass into the condition of tendrils. In this class, as in the former, there is no abrupt and sudden change, as many species both twine and climb by their leaf-stalks to some extent. We have an example of this in a species of Bignonia, the young shoot of which revolves, and is able to climb by twining round a vertical stick. Its leaf-stalk is sensitive, so that it acts also as a leaf-climber. The action of these organs, however, is very imperfect, and could not be depended on for regular support; the plant is, therefore, provided with tendrils. On its leaf-stalk there are two leaflets, and beyond them a sort of foot formed from the stalk, and three little toe or finger like projections which terminate in short and curved hooks. When touched these tendrils close and firmly hold any object presented to them, just like a hand. This plant, therefore, possesses to some extent the characters of twiner, leaf-climber, and tendril-bearer in one. Some plants have tendrils adapted for holding on to walls or other flat surfaces. When they meet such they turn their branches towards it and spread them widely in order that they may bring all their hooked tips into contact with it. After a short time these hooks swell up and form on the under side little discs or cushions, which probably secrete some sort of resinous substance as they adhere firmly to the flat surface. The tendrils of some plants have a curious habit of searching for holes or crevices in which to insert themselves, and will bend round almost to a right angle to reach an opening, behaving in this way something like a rootlet. In fact, the variations in the methods they adopt to accomplish their purpose are endless. One remarkable phenomenon exhibited by tendrils is contraction after they have fixed themselves. With few exceptions, they begin to wind or twist themselves in a spiral or corkscrew fashion after they have seized a support. From this the plant derives some important advantages. The length of the tendril is, in the first place, reduced by the twisting, and this, of course, draws the stem closer to or higher up the support, so that it climbs something like a sailor up a rope hand over hand, or grasping the support above its head drags itself up by the contraction of the tendrils. Another purpose served by this twisting is to make the tendrils more elastic and yielding without breaking, just like a coiled spring which may be drawn out considerably and when released will spring back again to its former position. In any violent movements of the plants, caused by wind or otherwise, the tendrils, therefore, act as springs, and allow the stems to sway backwards and forwards without being torn from their supports. Some plants without any particular adaptation, just as it were, scramble up neighbouring objects, others climb by hooks alone, and others again develop rootlets which grow round the trunks of trees or other objects and clasp them firmly. These methods, however, are comparatively rare and unimportant, and we may conclude that most climbing plants ascend their supports by their revolving and twining stems, their sensitive leaf-stalks, or their tendrils.

CARNIVOROUS PLANTS.

THAT some plants are carnivorous, and possess the power of capturing, killing, and digesting insects and other small animals, may seem to many not a little remarkable, as such power is usually associated with animals alone. It is, nevertheless, true; and if we consider the matter carefully, it does not appear so very surprising after all. It is known that all animals and plants are alike formed from that curious substance protoplasm, which possesses, in an elementary form, all the essential attributes of life; and that the differences which are observed between them are due to modifications of the powers of the original protoplasm, or to their development in particular directions. Thus, in one set of protoplasmic cells movement may be more prominently developed, in another set sensitiveness to stimuli, in a third the power of digestion and assimilation, and so on. It is not unlikely, therefore, that some power which is found most fully developed in the animal kingdom may also occasionally appear in the vegetable, when circumstances call it forth. Thus, although, as a rule, plants feed by their roots drawing up nourishment from the soil, and by their leaves absorbing carbonic acid from the atmosphere, yet there may be cases where, in addition to these methods, there may be the additional one of capturing and consuming animals. It must be remembered, also, that digestion, or the power of converting insoluble substances into soluble and easily diffused substances which can circulate freely through the tissues, is not confined to animals, but is possessed also by plants. In carnivorous plants, therefore, it is not the digestion itself that is remarkable, but only the peculiar arrangements and methods by which it is brought into use, which in many respects resemble traps and other appliances used by man himself for similar purposes.

Carnivorous plants belong to many different orders, and are found in various parts of the world; in Britain, America, India, Australia, &c. They usually inhabit damp heaths, bogs, marshes, &c., where water is abundant. This is no doubt necessary for a supply of fluid to keep up their copious secretions, on which much of their peculiar power depends. In this country the common Sundew is a most interesting specimen of this class of plants. It has very small roots, and bears five or six leaves, which spread out like a sort of rosette round the flower-stalk. The upper surfaces of these leaves are covered with glands bearing great numbers of little filament-like tentacles, and each gland is surrounded with fluid like a little drop of dew. This fluid is viscid or sticky, but is also transparent and glittering, and its appearance has given the name to the plant. The tentacles are exceedingly sensitive, and may be excited by the slightest touch, although not by wind or rain, a very necessary provision to save useless work. A solid, though insoluble, will cause them to act at once, and so slight is the stimulus required that a bit of human hair, weighing only about the eighty thousandth part of a grain, will set them in motion. This is far beyond what can be appreciated by our sense of touch. The absorption of certain nitrogenous fluids also excites their action, and when in this state the fluid secretion becomes acid and greatly increased in quantity. Now, when animals digest food their stomachs secrete a ferment called pepsin, and also hydrochloric acid, and both are necessary for the process, which will not proceed with the pepsin alone, nor yet with the acid alone, although it is not necessary that it be hydrochloric acid; other kinds will do, but an acid of some kind must be present. When the stomach is mechanically excited acid alone is secreted; but for the production of pepsin there must first be an absorption of a minute quantity of already soluble nitrogenous matter. The fluid secretion of the Sundew acts in an exactly analogous manner; it contains various organic acids, and also a ferment, which attack and digest the food which it seizes. Darwin fed numerous plants with roast beef and little cubes of white of egg, over which the tentacles bent, and copious secretions were poured forth, and the solids were speedily dissolved and digested, just as in the stomach of an animal.

It is now possible to follow the action of the Sundew as it seizes and devours its prey. Some unwary fly, attracted perhaps by the glittering little dewdrops or odour from the plant, comes too near the dangerous liquid, and touches one or two of the tentacles, which become at once excited, and bend towards it, and its doom is sealed. The sticky fluid entangles it directly, and in spite of its struggles the poor victim is seized; and then a curious movement is set up. The tentacles first touched bend to their next neighbours, to whom they hand over the fly; these in turn pass it to the next, and so on, until it arrives at the centre of the leaf, with the tentacles bent over it from all sides, and sometimes the leaf itself also curls, to form a sort of cup-shaped cavity, into which the acid secretion is poured in great abundance, and in about a quarter of an hour the breathing apparatus of the fly is choked up, when it dies, and is rapidly thereafter digested and its juices absorbed. The trap has been skilfully set, the bait affixed, and the victim caught, eaten, and digested. In order to prove that the plant was really nourished by this mode of feeding, Mr. Francis Darwin made some interesting experiments. He took six plates full of thriving plants and divided off each by a transverse bar. Then, choosing the least flourishing side of each, he placed roast meat in morsels of a tenth of a grain on the leaves, and renewed the dose occasionally. The plants on the fed side were soon clearly greener than those on the starved side, and their leaves contained more chlorophyll and starch. In less than two months the number of flower-stalks was half as numerous again on the fed as on the unfed side. After some months the flower-stalks were cut, when the numbers on the fed side were to those on the unfed as 165 to 100, and the weight 230 to 100. In the seed-vessels these proportions were even greater, being as to number 194 to 100, and as to weight 380 to 100. This experiment clearly proved that this carnivorous plant was nourished in a very great degree by the supplies of nitrogenous food given to it through its leaves.

In other plants arrangements of a somewhat different kind from those of the Sundew are found. Thus, in the Venus Fly Trap each leaf has two lobes, as it were, hinged on a stout mid-rib, and inclined at about a right angle to each other. The upper surface of each lobe is covered with glands filled with fluid, and also three little sensitive hairs or spikes jointed at the base, so that on the lobes closing they fall down flat on the surface. On the edges of the leaves there are tooth-like projections which fit into one another when the lobes close like the teeth of a rat-trap. When an insect touches the three hairs, which are extremely sensitive, the lobes close up sharply, the teeth interlock, and the insect is a prisoner. If very small it may escape, but if of any size it is firmly held, and the lobes press more and more firmly together until its form may be discerned from the outside through the tissues of the leaves. Thus a temporary sack or stomach is formed, into which the glands pour their acid fermenting secretion, which rapidly dissolves the insect. Over insoluble bodies the leaves close, but open again in some hours, when they are at once ready to act again; but if they have closed over nitrogenous substances, they remain shut for several days, and after reopening seem to become torpid and incapable of further action. Even the most active leaves are rarely able to digest a meal more than twice or thrice during their lifetime. The movements of this plant in capturing insects are of considerable interest, as they resemble so nearly the contraction of muscles in animals.

There are some plants whose method of capture is very different from those we have described. They have no sensitive hairs or tentacles to grasp their victim, but are provided with long funnel-shaped leaves or pitchers, into which they lure the unsuspecting insect, and from which there is no return. Hope must be left behind by all who enter the slippery path. Among these is the Sarracenia of North America. In this species the leaves are formed in a kind of trumpet-shape, with the wide-open end upmost, and this is protected by a widespreading lid, very often attractively coloured, and having its inner surface plentifully coated with sweet honey or nectar. Both the lid and trumpet-mouth secrete this pleasant fluid. To make the way of destruction more tempting to the lover of pleasure, a pathway is provided from the ground along the broad wing of the trumpet, and this also is sometimes coated with honey. The unsuspecting insect climbing up this path and entering the mouth finds the way smooth and pleasant; but after he enters the latter, little spikes pointing downwards make his return difficult even should his fears be aroused. Slowly and surely he glides to the bottom of the treacherous cup, and once there, escape is hopeless, for sharp spikes like those on a jail-door in miniature present their points downwards on every side, so that he cannot climb upwards. Meanwhile fluid is plentifully poured down until death ensues by drowning. This plant, however, is destitute of digestive power, and simply absorbs the juices of the decaying organism. Consequently there often accumulate in the pitchers quantities of decaying organic matter, into which insects drop their eggs. This sometimes leads to the destruction of the pitcher, as birds occasionally rip it open in order to devour the maggots, &c., which it contains.

The Nepenthes is another plant of very much the same nature as the foregoing. It is an inhabitant of the warmer parts of the Indian Archipelago, Ceylon, tropical Australia, and other warm countries. At the end of its leaves there is a long tendril-like projection which bears at its end a sort of pitcher, which is sometimes of considerable size, varying from an inch to a foot and more in depth. The mouth of the pitcher has a thickened rim, which helps to keep the mouth open to receive its prey. This rim is often prolonged inwards like a funnel, and of course acts in preventing the return of any insect which once passes through it into the pitcher beneath; sometimes it is provided with incurved hooks strong enough even to retain a small bird. The mouth of the pitcher, as well as the lid, is baited with honey, and the path downwards is easy and smooth, something like the Sarracenia. Instead of the teeth, however, there is always present a plentiful supply of fluid, which has generally an acid reaction, and is capable of true digestion, dissolving even cartilage.

In addition to those described, there are several other carnivorous plants which adopt methods of capture somewhat similar. Thus there is an aquatic species allied to the Venus Fly Trap which pursues its vocation in water. It has the lobes of its leaves slightly open, and catches crustacea, &c., as it floats about like a sort of net. Another species is provided with a bladder about the tenth of an inch in length, with six or seven long bristles around the mouth, which is fitted with a transparent valve opening inwards, which can be readily pushed back by any insect on entering. This species does not, however, really digest its prey, but merely absorbs the products of decomposition. There is also the Portuguese Fly-Catcher, very similar in many respects to the Sundew, but it is incapable of movement, the insects being caught only by the sticky nature of its secretions. So effective, however, is this for the purpose, that the plant is often hung up for catching and destroying flies, which it does in great numbers.

THE END.

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